# SOME STUDIES OF OAK LEAF BLISTER

# (*TAPHRINA CAERULESCENS*)

by

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I.J.S.

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# INTRODUCTION

Desmazières (1848) originally described the fungus upon which the present paper is based as Ascomyces caerulescens Montagne and Desmazières.* It was later transferred to Taphrina by Tulasne (1866). Various workers have noted morphological variations between host forms which induced some to subdivide the species by describing new species, but only one species, Taphrina caerulescens (Mont. & Desm.) Tul., is now recognized (Mix, 1949).

In this paper a brief review of the history of the name Taphrina caerulescens is presented together with distributional data as recorded in the literature. Some additional data has been obtained by correspondence from various herbaria in the United States and Canada.

The work that has been done on the morphology of the ascus and mycelium in the leaf was reviewed. Intraspecific physiological variations, as expressed in amount of growth on agar with different nitrogen sources, were studied. These results have been compared with those of earlier experiments (Mix, 1952) using the same nitrogen sources but grown in liquid culture.

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*In Desmazières' description, he cites Montagne as joint author.

## REVIEW OF THE LITERATURE

Desmazières (1848) described a new genus Ascomyces which was characterized by ascus-like sporangia on the surface of the host leaf. In the same paper he described a new species, Ascomyces caerulescens, occurring on leaves of Quercus coccifera L.

Cooke (1878) described a new species, Ascomyces quercus Cke., on leaves of Q. cinerea Michx. This was later reduced to synonomy with Taphrina caerulescens by Robinson (1887) and by Farlow (1888).

Thümen (1880) described a new species, A. alutaceus Thm., on leaves of Q. pubescens Willd. This was redescribed on leaves of Q. robur L. by Saccardo (1882). It was reduced to synonomy by Giesenhagen (1895).

Trelease (1884) reported the occurrence of A. caerulescens on Q. coccinea Muensch and Q. rubra L. These were new hosts for A. caerulescens.

Because the new genus Ascomyces was not clearly differentiated from the previously described genus Taphrina (Fries, 1825), Tulasne (1866) revised Fries' description of Taphrina and reduced Ascomyces to synonomy.

Sadebeck (1884) reduced Taphrina and Ascomyces to synonyms of Exoascus (Fuckel, 1860), but Taphrina has priority.

Peck (1886) described a new species, Ascomyces extensus Pk., from leaves of Quercus macrocarpa Michx. and (1887) A. rubrobrunneus Pk. from leaves of Q. rubra.

Robinson (1887) agreed with Sadebeck (1884) that a single genus should be recognized but like Johanson (1886) concluded that it should be called Taphrina. He listed Taphrina caerulescens as occurring in America and stated that A. quercus Cke. was synonomous with T. caerulescens.

Saccardo (1889) recorded the species on Q. cinerea as Taphrina quercus (Sacc.) Tul. instead of A. quercus disregarding Robinson (1887) who had reduced this name to synonomy with T. caerulescens. No mention of T. quercus appears in later literature.

Farlow (1888) in his Host Index referred to the following as occurring in North America: A. quercus on Q. alba L., Q. cinerea, Q. coccinea, Q. douglasii Hook and Arn., Q. laurifolia Michx.; and A. extensus on Q. macrocarpa assigning them to T. caerulescens. He recognized A. rubrobrunneus on Q. rubra as a distinct species.

Massalongo (1894) reported the following as "new" hosts for T. caerulescens: Q. cerris L., Q. pedunculata Ehrh. (Q. robur), and Q. pubescens.

Sadebeck (1893) in a new classification divided the genus into three genera: Exoascus, Taphrina, and Magnusiella Sadebeck. The species caerulescens was classified under the genus Taphrina.

Giesenhagen (1895), while accepting Sadebeck's Magnusiella, supported the idea of one genus for all other forms. He divided Taphrina into four subgenera according to the shape of the ascus: (1) Filicina, (2) Betula, (3) Pruni, and (4) Magnusiella. Taphrina caerulescens fitted imperfectly into the Betula group.

Patterson (1895) did not differentiate between host forms of T. caerulescens according to size and shape of the ascus as a whole, but differences in diameter and shape of the base of the ascus were noted.

Jaczewski (1926) distinguished a variety as T. caerulescens var. Quercus-coccifera Jacz. on Quercus coccifera because of characteristic rhizoids projecting between epidermal cells from the subcuticular asci.

Jankowska (1928) distinguished two main types of asci in T. caerulescens: (1) clavate asci, gradually narrowed to a point at the base and inserted; and (2) cylindrical asci, sessile on a broad base.

Thompson (1940) found morphological differences in the asci and their manner of insertion between the epidermal cells of the hosts in strains of T. caerulescens growing upon different species of Quercus. She reduced T. rubrobrunnea (Pk.) Sacc. to synonomy with T. caerulescens. She retained T. kruchii (Vuill.) Sacc. as a separate species because of its formation of witches brooms on the host.

Mix (1949) agreed with Thompson in recognizing Taphrina caerulescens and T. kruchii as the two species occurring on Quercus. He also described morphological differences between certain additional host forms.

## INOCULATION EXPERIMENTS

Results of attempts at artificial inoculation of species of Quercus with Taphrina caerulescens have so far been inconclusive. Several reports have appeared in the literature of inoculation experiments performed both in the greenhouse and out-of-doors.

Martin (1925) reported successful outdoor inoculation of burr oak seedlings, presumably Q. macrocarpa, sprayed with a spore suspension of T. caerulescens isolated from Q. nigra L. Seedlings were sprayed on May 11 and on June 4 Martin first observed hyphae entering the stomata taking 24 days before infection apparently took place. Mix (1949) reported that two of Martin's supposed T. caerulescens cultures were misidentified and were a species of Rhodotorula Harrison. Apparently this was true of the culture she used on the burr oak seedlings.

Thompson (1940) inoculated specimens of three oaks, Q. macrocarpa, Q. palustris Moench. and Q. muhlenbergii Engelm., with cultures from the following six hosts: Q. marilandica Muench., Q. maxima Ashe, Q. virginiana Mill., Q. velutina Lam., Q. laurifolia and Q. kelloggii Newb. No infection resulted, presumably because of a dry period which followed.

On April 1, 1950, twenty seedlings of Quercus macrocarpa, transplanted to pots in the fall of 1949, were placed in the greenhouse and equally divided into Group A and Group B. Both Group A and Group B were inoculated by a hand sprayer with a spore suspension from a culture of Taphrina caerulescens which had been isolated from Q. macrocarpa. The seedlings of Group A were then placed in a glassed chamber. Both seedlings with dormant buds and opening buds were kept wet by a fine spray of water for 24 hours after inoculation. The seedlings of Group A were then removed from the moist chamber and placed on a bench in the greenhouse. The seedlings of Group B remained in the moist chamber under the same conditions for 48 hours, then removed from the moist chamber and placed on the bench with Group A.

The same treatment was given to 20 seedlings of Q. velutina and 20 seedlings of Q. prinoides L. These were inoculated with T. caerulescens isolated from Q. velutina and Q. prinoides respectively.

A number of seedlings of Q. imbricaria Michx. were inoculated with cultures of T. caerulescens isolated from Q. palustris and Q. marilandica.

In no case did any characteristic blisters develop.

On April 24, 1950, the following outdoor inoculations were performed. Cells from eight cultures of T. caerulescens isolated from Q. marilandica, Q. maxima, Q. palustris, Q. coccinea, Q. prinoides, Q. velutina, Q. macrocarpa and

Quercus kelloggii were each sprayed by a hand sprayer onto branches with partially opened buds of Q. marilandica, Q. velutina, Q. prinoides, Q. alba and Q. imbricaria.

Three inspections of the inoculated oaks were made at three-week intervals. No positive results were observed.

A similar set of inoculations was made on April 19, 1951, with no infection resulting.

The fact that Taphrina caerulescens does not readily lend itself to artifical inoculation suggests several possible explanations.

1. The conditions of infection may be very restricted in regard to such factors as temperature, humidity, period of dormancy of blastospore (over-summering and over-wintering), time inoculum should be applied, etc.

2. The host specialization of T. caerulescens may have gone beyond the species level so that strains of the fungus may be restricted to certain taxa within a species of Quercus. There is no record of attempts to reinfect the original individual with a culture that was isolated from that host.

3. As in the case of some bacteria, T. caerulescens may lose its pathogenicity when maintained in pure culture. This seems improbable, however, as in a number of other species of Taphrina, successful inoculations have been made from pure cultures (Klebahn, 1923; Wieben, 1927) and Mix (1935) obtained successful inoculations with an isolate of T. deformans (Berk.) Tul. maintained in pure culture 11 years.

Further investigations are necessary on artificial inoculations with Taphrina caerulescens.

Because of similarity of this disease to peach leaf curl, T. deformans, much of the knowledge of peach leaf curl has seemed applicable to oak leaf blister. Dormant sprays which have effectively controlled peach leaf curl apparently control oak leaf blister (Weber, 1941; Hepting, 1951).

By analogy with the peach leaf curl, the life history of the fungus may be conjectured to be as follows. Overwintering blastospores are either washed or carried by air currents into the opening buds of Quercus in early spring. If this dissemination is followed by a rainy period of some length, a high incidence of infection occurs. Because the asci are usually formed on the lower surface of the leaf it may be that infection occurs on that surface, but in heavy infections asci appear on both surfaces of the leaf. In many other species of Taphrina the asci form on both surfaces of the same lesion so the position of the asci is not necessarily an indication of the place of infection. However, the writer in making hand sections of very young lesions found the mycelium only between the lower epidermal cells and the cuticle. The fungus grows under the cuticle stimulating host cells to enlarge and divide. This gives rise to a bulge in the leaf whose outline is circular. Asci, forming ascospores, are present in a few weeks after infection. The ascospores begin budding immediately in the ascus and the blastospores

are explosively ejected by the rupturing ascus. No perennial mycelium has ever been found.

Because dormant sprays have been effective in control of peach leaf curl, we can assume that much of the inoculum must over-winter on the twigs, and is washed onto unfolding leaves in the spring. It is possible that the blastospores over-winter on soil, leaves or other debris and are carried by air currents back to the new leaves in the spring.

## DISTRIBUTION DATA

To accumulate additional information on the distribution of Taphrina caerulescens letters were sent to the herbaria of United States and Canada requesting lists of their collections. At the time of this writing some of these lists are still being received, therefore this information is not complete.

Taphrina caerulescens is apparently wide-spread in United States and Canada. In the United States it has been collected in Maine on Quercus maxima; as far south as Florida on Q. laurifolia, Q. nigra and Q. phellos L.; as far west as California on Q. agrifolia Née, Q. chrysolepsis Liebm., Q. douglasii, Q. lobata Lee and Q. kelloggii; and northwest to Utah and Wyoming on Q. gambelii Nutt.

In Canada collections of T. caerulescens have been made from Nova Scotia in the east as well as from Quebec, Ontario, Saskatchewan, and west to Alberta.

In following the nomenclature of Rehder (1947), 33 species of Quercus are reported as having oak leaf blister from 33 different states.. Though the disease has also been reported from several foreign countries only the collections made in United States and Canada are recorded here. In many cases lists of collections were received from various herbaria and specimens were not seen.

Though leaf blister of oaks is wide-spread, it rarely causes damage of much economic importance. However, in the Gulf and South Atlantic states light to heavy infections occur on leaves every year indicating need for some control practices (Wedgeworth, 1926; Weber, 1941; Marshall, 1948; Hepting, 1951).

The following is a partial list of collections of Taphrina caerulescens in United States and Canada.

Quercus agrifolia Née

CALIFORNIA: Monterey Co., June 16, 1932, H. N. Hansen; 1935, H. N. Hansen (U.S.D.A., P & MC 7400); Monterey Co., April, 1938, H. Earl Thomas.

Quercus alba L.

MASSACHUSETTS: Waltham, June 20, 1935, D. H. Linder. NEW YORK: Ithaca, June 28, 1936, W. W. Ray (Penn. State Fungi, No. 27354); Ithaca, 1938, id. VIRGINIA: Victoria, June 9, 1936, S. A. Wingard.

Quercus borealis Michx.

CANADA: Quebec, Kingsmere, June 29, 1938, H. H. W. (Penn. State Fungi, No. 27366); Ontario, Ottawa Constance Bay, June 30, 1938, id. (Penn. State Fungi, No. 27368). CONNECTICUT: East Granby, July 4, 1934, H. G. Eno (U.S.D.A. For. Path. 81724). MASSACHUSETTS: Petersham, July 26, 1928, J. S. Boyce (Herb. J.S.B. 2028); Granville, Sept. 4, 1888, A. B. Seymour (Ex. Herb. A.B.S.)(P & MC). MICHIGAN: Cherboygan, July 13, 1920, E. J. Jenkins (68876); Huron Co., Sand Point, near Bayport, July 4, 1938, E. A. Bessey. NEW HAMPSHIRE: Conway, June 8, 1921, P. Spaulding (For. Path.

45371). TENNESSEE: Great Smoky Mts., Nat. Park, Rich Mt., June 24, 1934, L. R. Hesler. VIRGINIA: Hot Springs, July 17, 1924, P. Gravatt and E. J. Jenkins.

Quercus bushii Sarg.

KANSAS: Leavenworth, Leavenworth Co., June 12, 1949, R. L. McGregor; Linwood, 2 mi.w., "Indian Spring", June 15, 1949, id.; Linwood, 2 mi.w., "Indian Spring", June 16, 1949, R. H. Thompson; Baldwin, 5 mi.w., Douglas Co., July 8, 1950, I. J. Shields; Vinland, Violet Hill, Douglas Co., June 8, 1951, R. L. McGregor and A. J. Mix; Garnett, 2 mi.s., Anderson Co., June 4, 1951, R. L. McGregor.

Quercus chrysolepsis Liebm.

CALIFORNIA: San Diego Co., Galley's Ranch, Alt. 5,000 feet, July, 1896, S. G. Stokes.

Quercus coccinea Muench.

GEORGIA: Athens, May 14, 1936, J. H. Miller. MARYLAND: Tekoma Park, June, 1903, C. L. Shear (P & MC); Lanham, June 21, 1910, W. T. Slough, J.A.S. (P & MC); Tekoma Park, June 24, 1913, C. L. Shear, (Herb. J.R.W. 380)(P & MC); Hazelton-Luzirne Co., July 4, 1919, W. A. McCubbin (P & MC). MICHIGAN: Grayling, Sept., 1902, W. J. Beal (P & MC); Huron Co., Sand Point, near Bayport, July 4, 1938, E. A. Bessey. NEW YORK: Westbury, Herb. Perley Spaulding No. 102; Ithaca, Tree n. of Gym, June 30, 1890, W. R. Dudley; Junius, Near west swamp, July 8, 1916, Whetzel and Jack. (Penn. State Fungi, No. 8818); Ithaca, June 30, 1936, W. W. Ray (Penn. State Fungi, No.

27355); Ithaca, South Hill Marsh, June 26, 1940, A. J. Mix. RHODE ISLAND: Barrington, Hamden Meadows, June 21, 1910, det. A. E. Jenkins (Herb., J. Franklin Collins No. 5582). VIRGINIA: Elliott, Elliott Bald Mt., May 29, 1923, W. W. Dield (x P. & MC.); Falls Church, July, 1937, C. L. Shear, detl J.A.S. (P & MC); White Top, July 14, 1937, id. WISCONSIN: Stoughton, Leg., Wm. Trelease (Ellis North American Fungi, No. 1499).

Quercus dentata Thunb.

SASKATCHEWAN: Indian Head, July 25, 1935, B. J. Sollano (Herb. Univ. Toronto).

Quercus douglasii Hook. and Arn

CALIFORNIA: Lake Co., May 3, 1936, H. N. Hansen.

Quercus ellipsoidalis E. J. Hill

WISCONSIN: Lyndon Station, July 4, 1917, J. J. Davis (Herb. Univ. Wisconsin).

Quercus falcata Michx.

ALABAMA: Auburn, (Atkinson Local Collection No. 1160). GEORGIA: Washington, June 11, 1898, E. F. Andrews (Herb. F. Wamb. Patt.); Albany, May, 1937, R. Cole and W. W. Diehl.

Quercus gambelii Nutt.

WYOMING: Medicine Bow Nat. For., Hayden Divn., Sandstone Ranger Sta., July 13, 1939, W. G. Solheim.

Quercus geminata Small

NORTH CAROLINA: May, 1936, R. F. Poole.

Quercus georgiana Curtis

GEORGIA: Stone Mt., April 26, 1925, J. H. Miller (Herb. Univ. Georgia).

Quercus ilicifolia Wang.

NEW HAMPSHIRE: W. Ossipee, July 19, 1910, W. G. Farlow (Farl. Herb.). NEW YORK: Sam's Point, Aug., J. Dearness (Herb. J. D.). VIRGINIA: Bald Knob, July, 1918, G. H. Chapman (Herb. Mass. Agric. Coll. 2486).

Quercus imbricaria Michx.

MISSOURI: Perryvale, C. H. Demetrio (Rab-Pazsch. F. Eur.). NORTH CAROLINA: Greensboro, June, 1934, A. F. Thiel; ibid., spring, 1934, E. M. Martin.

Quercus kelloggii Newb.

CALIFORNIA: Lake Co., May 3, 1936, H. N. Hansen; Monterey Co., (9108 Herb., James R. Weir) det. Mrs. Patt.

Quercus laurifolia Michx.

FLORIDA: Fort Barreneas, Sept. 7, 1924, W. Wilson det. A. E. Jenkins; Gainesville, May 20, 1935, G. F. Weber; ibid., April 28, 1941, id.

Quercus lobata Née

CALIFORNIA: 1935, H. N. Hansen.

Quercus macrocarpa Michx.

ALBERTA: J. Dearness (Herb. J. D.). IOWA: W. Okeboji, June 19, 1932, G. W. Martin. KANSAS: Hays, June 6, 1930, E. Bartholomew (N.A.F. 10957, as T. extensa); Baxter Springs, July 31, 1948, R. L. McGregor; Lawrence, May 14, 1946, A. J. Mix; Pittsburg, July 5, 1948, R. L. McGregor; Baxter Springs,

Cherokee Co., July 31, 1948, id.; Franklin Co., 5 mi. n.e. of Ottawa, May 20, 1949, id.; Leavenworth, Leavenworth Co., June 12, 1949, id.; Pleasanton, Linn Co., June 14, 1950, I. J. Shields. WISCONSIN: Granville, July 17, 1867, I. A. Lapham.

Quercus marilandica Muench.

KANSAS: Baldwin, June, 1933, A. J. Mix; ibid., June 2, 1936, id.; ibid., May 31, 1937, id.; Baxter Springs, Cherokee Co., July 31, 1948, R. L. McGregor; Kent, Leavenworth Co., May 29, 1948, id.; Garnett, Anderson Co., June 19, 1949, id.; Osage Co., 1 1/2 mi. n. of Vasser, June 18, 1949, id.; Douglas Co., s. of Vinland, June 1 and 22, 1949, A. J. Mix; Pleasanton, Linn Co., June 14, 1950, I. J. Shields; Douglas Co., s. of Vinland, June 7, 1950, id.; ibid., July 13, 1950, id.; Vinland, Violet Hill, Douglas Co., June 8, 1951, A. J. Mix; Anderson Co., 2 mi. s. Garnett, June 4, 1951, R. L. McGregor; Johnson Co., 2 1/2 mi. s. Stanley, June 3, 1951, id. MASSACHUSETTS: College, Jan. 22, 1921, L. E. Miles (135 A & M). MISSOURI: Seligman, July 12, 1922, R. P. White; Bagnell Dam, Osage Beach, June 3, 1937, A. J. Mix. VIRGINIA: South Boston, May 25, 1909, C. W. Maxwell (P & MC); Princess Anne Co., May 18, 1926, H. T. Cook.

Quercus maxima Ashe

CONNECTICUT: New Haven, June 23, 1928, A. J. Mix; ibid., June 30, 1928, id.; Collinsville, Aug., 1937, id.

GEORGIA: Athens, May 14, 1936, J. H. Miller; Experiment, May 18, 1936, J. L. Weimer. KANSAS: Linwood, 2 1/2 mi. s., Indian Spring, June 16, 1949, R. L. McGregor; Franklin Co., 5 mi. n.e. Ottawa, May 20, 1949, id.; Osage Co., 1 1/2 mi. n. Vassar, June 18, 1949, id.; Baldwin City, Baldwin Woods, June 7, 1950, I. J. Shields. MAINE: Kittery Point, June, 1899, R. Thaxter (Farl. Herb.). MASSACHUSETTS: Manchester, Sept. 4, 1928, R. J. Eaton (For. Path. 45878); Sunderland, Aug., 1934, R. H. Thompson; Amherst, Aug. 19, 1937, A. J. Mix. NEW HAMPSHIRE: Canaan, Sept. 23, 1931, E. D. Farnsworth (For. Path. 51682). NEW YORK: Sandlake, Sept., 1886, C. H. Peck (Type of T. rubrobrunnea); Columbia Co., near Hudson, Aug., 1919, A. J. Mix; Walton, June 30, 1924, Mrs. Frances A. Jenkins, det. A. E. Jenkins; ibid., July 10, 1924, id.; Poultry Woodlot, Aug. 18, 1929, D. S. Welch (Herb. D.S.W. 819); Klinewoods Road, June 21, 1940, A. J. Mix; Ithaca, Fall Creek Ravine, near Beebe Lake, June 27, 1940, id. NORTH CAROLINA: 1937, J. N. Couch (Herb. Univ. North Carolina, 10724). ONTARIO: Muskoka, Muldrew Lake, July 31, 1936, D. S. Welch (Herb. D.S.W. 1286). TENNESSEE: June 20, 1937, C. D. Sherbakoff. WISCONSIN: June 2, 1913, J. J. Davis (Herb. Univ. Wisconsin).

Quercus nigra L.

ALABAMA: Auburn, Lee Co., May 8, 1890, G. F. Atkinson (Econ. F. 180); ibid., May 13, 1890, id. (Penn. State Fungi, No. 18095); ibid., April 24, 1897 (Alabama Biological Survey); ibid., April 18, 1912, F. A. Wolf. FLORIDA: Deland, March 23, 1925, A. E. Jenkins (P & MC, 68576); Gainesville, April 9, 1936,

E. West (Penn. State Fungi, No. 25244); ibid., April 28, 1941, G. F. Weber. GEORGIA: Tallapoosa, May 23, 1898, C. F. Diffenderfer; Tifton, M. K. Bryan and V. K. Charles (P & MC, 66520); Camella, May 14, 1923, J. D. Gardner and A. M. Waterman (Forest Path. Providence R.I. 2368). LOUISIANA: Ferriday, July 17, 1931, L. O. Overholts (P & MC). MASSACHUSETTS: Melrose, June 16, 1936, R. H. Thompson. MISSISSIPPI: Long Beach, April 16, 1921, L. E. Miles (P & MC, 136); Lucedale, May 16, 1922, id., (P & MC 731); Biloxi, July 7, 1922, id., (P & MC 741). NORTH CAROLINA: Durham, F. A. Wolf (Herb. Univ. Tennessee 9978); Winterville, June 26, 1905, F. L. Stevens, det. J.A.S. (P & MC); Leicester, June 4, 1909, B. B. Higgins, No. 2079 (P & MC); Wellets, July 21, 1931, L. O. Overholts, P. V. Siggers, and F. Kangert (P & MC). SOUTH CAROLINA: Columbia, Atkinson local collection, No. 1991.

Quercus palustris Muench.

CONNECTICUT: Redgefield, July 6, 1901, A. S. Apgar (D. W. Veg.). GEORGIA: Athens, May 14, 1936, J. H. Miller. KANSAS: Columbus, June 24, 1929, Coll. & det. R. W. Davidson, No. 8 (P & MC).

Quercus phellos L.

ALABAMA: Auburn, May 8, 1890, G. F. Atkinson. FLORIDA: Lake City, April 30, 1900, H. H. Hume (Fungi of Fla. Distrib.). GEORGIA: Fitzgerald, May, 1930, M. K. Bryan and V. K. Charles (P & MC). NORTH CAROLINA: 1938, F. A. Wolf. VIRGINIA: Haymarket, June 18, 1937, H. A. Allard, J.A.S. (P & MC).

Quercus prinoides Willd.

KANSAS: Vinland, Violet Hill, May 14, 1946, A. J. Mix.

Quercus rubra L.

ALABAMA: Auburn, May 13, 1890, G. F. Atkinson (Econ. F. 185). GEORGIA: Manelta, June 7, 1900, A. S. Burnap (Dir. Veg. Path.); Experiment Sta., May 15, 1914, B. B. Higgins (P & MC). INDIANA: Surrey, July 30, 1917, C. Chupp (Penn. State Fungi No. 10637). MARYLAND: Anne Arundel Co., Harold Harbor, June 20, 1937, J.A.S. NEW HAMPSHIRE: Newport, July 8, 1909, P.S. (Herb. Perley Spaulding); Lyme Center, June 25, 1929, H. J. Lee (Penn. State Fungi No. 17597). NEW YORK: Ithaca, Sage College bridge, October, 1884, W. R. Dudley; ibid., July 1, 1890, id.; Ithaca, June 10, 1904, Whetzel and Jackson (Penn. State Fungi No. 1938); Romulus, June 28, 1907 (Penn. State Fungi No. 2502); ibid., (Penn. State Fungi No. 2772); Essex, July, 1909, P. Spaulding (P & MC); Oswego, July 16, 1910, R. S. Nanty (Penn. State Fungi No. 5431); Suffolk Co., Riverbead, June 12, 1923, Fernow (P & MC); Clayton, July 29, 1924, May Irwin (Forest Path. Providence, R.I.). NORTH CAROLINA: Durham, June, 1935, F. A. Wolf. PENNSYLVANIA: Lancaster, July 15, 1919, No. 385, J. A. McCubbin (Hub. J.R.W.); Gettysburg, June 5, 1924, R. S. Kirby; ibid., State College, July 14, 1924, id. WISCONSIN: Blue River, May, 1924, J. J. Davis.

Quercus stellata Wang.

ILLINOIS: Mount Vernon, Aug. 6, 1937, G. H. Boewe. KANSAS: Pleasanton, Linn Co., June 14, 1950, I. J. Shields; Anderson Co., 2 mi. s. Garnett, June 4, 1951, R. L. McGregor; Johnson Co., 2 1/2 mi. s. Stanley, June 3, 1951, id. SOUTH CAROLINA: Clemson College, June 15, 1935.

Quercus undulata Torr.

COLORADO: Mancos, June 22, 1898, Baker, Earle and Tracy (Farl. Herb.); Ouray, July 4, 1907, Clements (Crypt. Form Colo. 527).

Quercus utahensis Rydb.

COLORADO: Glenwood Springs, Aug. 20, 1941, A. J. Mix.

Quercus velutina Lam.

ARKANSAS: Fayetteville, May 21, 1935, J. C. Dunegan. CONNECTICUT: New London, June, 1886, W. G. Farlow (Farl. Herb.); New Haven, June 24, 1928, A. J. Mix; Collinsville, Aug. 17, 1937, id. KANSAS: Galena, July 3, 1948, R. L. McGregor; Kent, 1 mi. s., Leavenworth Co., May 29, 1948, id.; Crawford Co., 8 mi. n. Pittsburg, State Park #2, July 5, 1948, id.; Union town, Bourbon Co., July 5, 1948, id.; Franklin Co., 5 mi. n.e. Ottawa, May 20, 1949, id.; Linwood, 2 mi. s.w., Indian Spring, June 15, 1949, R. H. Thompson and A. J. Mix; ibid., June 16, 1949, R. H. Thompson; Ottawa, 4 mi. s.w., Franklin Co., June 18, 1949, R. L. McGregor; Woodson Co., Yates Center, 2 mi. n.w., June 19, 1949, id.; Douglas Co., s. of Vinland, June 23, 1950, I. J. Shields; ibid., July 13, 1950, id.;

Douglas Co., 5 mi. w. Baldwin, July 2, 1950, id.; ibid., July 8, 1950, id.; Douglas Co., 3 mi. n.e. Baldwin; July 13, 1950, id.; Leavenworth Co., 2 1/2 mi. s.w. Linwood, July 2, 1950, R. L. McGregor; Lecompton, Douglas Co., July 2, 1950, id.; Vinland, Violet Hill, Douglas Co., June 8, 1951, R. L. McGregor and A. J. Mix; Anderson Co., 2 mi. s. Garnett, June 4, 1951, R. L. McGregor; Franklin Co., 2 mi. s. Lane, June 4, 1951, id.; Miami Co., Murray Lake, June 3, 1951, id.; Johnson Co., 2 1/2 mi. s., Stanley, June 3, 1951, id. MARYLAND: Lanham, June 26, 1910, W. T. Swingle, det. J.A.S. MASSACHUSETTS: Middlesex Falls, A. B. Seymour; Middlesex Falls (Penn. State Fungi No. 5046); Pigeon Cove, July 28, 1890, id. (Econ. F. 184b); Hamilton, July, 1927, P. Spaulding (For. Path. 16130). MISSISSIPPI: Starkville, May 10, 1890, S. M. Tracy (Econ. F. 184a). MISSOURI: Camdenton, June 3, 1937, A. J. Mix; Neosho, 3 mi. n.e. Newton Co., July 2, 1948, R. L. McGregor; Joplin, 2 mi. w., Jasper Co., July 3, 1948, id. NEW YORK: Ithaca, Cascadilla woods, July 1, 1890, W. R. Dudley; Cayaga Lake Basin (Atkinson Local Coll. No. 534); Taughannock (Penn. State Fungi No. 2527); Mattituck, June 21, 1924, Rec. J. H. Vogel det. A. E. Jenkins (P & MC, 18542). VIRGINIA: Afton, June 18, 1925, Bernard Moves and M. Waterman (For. Path. Prov. R.I., 25199); Big Meadows, Shenandoah Nat. Park, July 2, 1938, J.A.S. (P & MC). WASHINGTON, D.C.: June 7, 1937, A. B. Nystrom det. A. E. Jenkins (P & MC). WEST VIRGINIA: Monongahela Co., near Lake Lynn, July 12, 1935, C. R. Orton.

WISCONSIN: Avoca, July 18, 1923, J. J. Davis (Herb. Univ. Wisconsin); Blue River, May, 1924, id.

Quercus virginiana Mill.

GEORGIA: Waynesboro, May 26, 1923, Hardin (Penn. State Fungi No. 18208); SOUTH CAROLINA: Landrum, May 16, 1924, N. F. Carpenter, det. A. E. Jenkins (P & MC, 8498). VIRGINIA: Princess Anne Co., May 21, 1935, H. T. Cook; ibid., May 18, 1936, id.

Quercus sp. undet.

LOUISIANA: Palmer Lake Providence (Penn. State Fungi, Nos. 21568, 21951).

## MORPHOLOGICAL STUDIES OF ASCI AND MYCELIUM IN THE LEAF

Desmazières (1848) described *Ascomyces caerulescens* as having no mycelium stating that the sporangium (ascus) constituted the entire fungus. Tulasne (1866) corrected this error and recognizing the possession of mycelium transferred the fungus to the genus *Taphrina*. Patterson (1895) recorded differences in diameter and shape of the ascus as already mentioned in Review of Literature. Jaczewski (1926) noted on the base of the ascus rhizoidal elongations projecting between the epidermal cells and on this basis described a variety, *Taphrina caerulescens* var. *Quercus-coccifera*. Jankowska (1928) recorded two types of asci: (1) clavate and (2) cylindrical. Thompson (1940) compared the differences of size and shape of the asci of *T. caerulescens* from 36 different species of *Quercus*. She found that the length varied from 30 to 120 microns and the width from 11 to 34 microns. The largest asci were found on leaves of *Quercus geminata* Small, *Q. coccinea*, *Q. douglasii*. The smallest asci were found on leaves of *Q. cerris*, *Q. macrocarpa*, and *Q. undulata* Torr.

Variations in shape were also noted, most of the asci being cylindrical or clavate and somewhat flattened at the apex. On a given host species there was considerable uniformity

as to size and shape of the asci; however, the manner of insertion or shape of the base of the ascus varied considerably.

Thompson further observed that two groups could be differentiated by examination of the bases of the asci; asci with one or more rhizoidal projections extending between epidermal cells, and asci with a tapering base and no projections. The asci formed on leaves of Q. kelloggii and Q. alba are representative of the rounded or more blunt base, while those asci formed on leaves of Q. borealis Michx. and Q. cerris frequently show deeply inserted projections or rhizoidal elongations. The character of the ascus base was not correlated with any particular ascus size, range of sizes, or group of hosts.

No special studies on ascus size or shape have been made by the writer but a number of observations were made that were in agreement with those of Thompson (1940).

In preliminary investigations, the writer found that in early development of the blister on a leaf of Q. velutina the mycelium followed the radial walls of the epidermal cells under the cuticle. The point of infection is presumed to be through the cuticle; penetration probably occurring soon after the bud opens and the leaves unfold. The mycelium continued its growth following the radial walls of the epidermal cells until the hyphae become much wider than the radial walls. If tangential hand sections are made of a fresh leaf through an infected area cutting just below the epidermis,

cleared in chloral hydrate, and observed in surface view, the hyphae form a network which in some cases occupies most of the area between cuticle and the epidermal cell. These hyphae become distinctly segmented and form the ascogenous cells which elongate to produce the asci.

Mix (1949) divides all species of Taphrina into three types as regards mycelial habit.

> Intercellular forms (Taphrina deformans, etc.) developing abundant mycelium between the interior cells of the leaf, stem, or fruit and subsequently forming a subcuticular layer of ascogenous cells; subcuticular forms (Taphrina epiphylla Sadeb., etc.) whose mycelium and ascogenous cells grow only beneath the cuticle; and wall inhabiting forms (Taphrina laurencia Gies., etc.) living entirely within the outer epidermal wall of the host.

Taphrina caerulescens has been considered by many past workers as forming only subcuticular mycelium; following the formation of the ascogenous cells under the cuticle. Sadebeck (1893) states that in the case of the genus Taphrina (as distinguished from Exoascus) the subcuticular mycelium differentiates into fertile and sterile cells, the former becoming mother cells of the ascogenous cells, the latter degenerating. Patterson (1895) reported and illustrated instances where the asci showed rhizoidal appendages which projected inwardly between cells of the epidermis. This indicated at least a tendency toward formation of intercellular mycelium. Such rhizoidal projections were also recorded by Thompson (1940) among the characteristic differences between host forms as to the occurrence of the rhizoids. Further study is needed

on the distribution of the mycelium of this fungus in the leaf.

The presence of the fungus under the cuticle and above the epidermal cells stimulates the cells of the leaf, causing them to increase in size and number. Apparently though infection may occur on either side of the leaf, the lower surface is probably most often the point of entrance. (See earlier discussion.)

# GROWTH OF *TAPHRINA CAERULESCENS* ON DIFFERENT NITROGEN SOURCES

## Statement and Purpose of the Problem

Several workers, acquainted with the morphological variations that occur between different host forms of *Taphrina caerulescens*, have described new species on different species of *Quercus*, others have thought it more feasible to recognize only one species. The question has arisen as to whether physiological variations occur, and if so, how they compare with the morphological variations. This investigation, prompted by results obtained in liquid culture by Mix (1952), was done to learn about some of these physiological variations and to compare results obtained in agar culture with those in liquid culture.

## Materials and Methods

In these experiments twenty-six isolates of *T. caerulescens* from 13 species of oak were grown in agar media. The organisms used are listed in Table I (on the following page). In all cases the isolations had been made by Dr. A. J. Mix.

The purpose of these experiments was to learn if the various isolates exhibited differences as they were grown on

TABLE I

DATA ON ISOLATES OF TAPHRINA CAERULESCENS

| *T. caerulescens* Isolates of *Quercus* Species | Stock Number | Date of Isolation | Location of Host | Collector |
|---|---|---|---|---|
| alba | 398 | June 9, 1936 | Victoria, Va. | S. A. Wingard |
| | 399 | June 9, 1936 | Victoria, Va. | S. A. Wingard |
| bushii | 375 | June, 1949 | Lawrence, Ks. | A. J. Mix |
| | 384 | June, 1949 | Lawrence, Ks. | A. J. Mix |
| coccinea | 348 | May 18, 1936 | Athens, Ga. | J. H. Miller |
| | 790 | June 26, 1940 | Ithaca, N.Y. | A. J. Mix |
| ilicifolia | 376 | June, 1945 | Ellendale, Del. | A. J. Mix |
| | 217 | June, 1945 | Ellendale, Del. | A. J. Mix |
| laurifolia | 252-276 | May 1, 1941 | Gainesville, Fla. | G. F. Weber |
| | 237 | May 1, 1941 | Gainesville, Fla. | G. F. Weber |
| macrocarpa | 880 | June, 1946 | Lawrence, Ks. | A. J. Mix |
| | 881 | June, 1946 | Lawrence, Ks. | A. J. Mix |
| marilandica | 253 | June 7, 1933 | Vinland, Ks. | A. J. Mix |
| | 322 | June, 1949 | Vinland, Ks. | A. J. Mix |
| maxima | 355 | May 18, 1936 | Athens, Ga. | J. H. Miller |
| | 767 | June 21, 1940 | Ithaca, N.Y. | A. J. Mix |
| nigra | 324 | May 1, 1941 | Gainesville, Fla. | G. F. Weber |
| | 361 | May 1, 1941 | Gainesville, Fla. | G. F. Weber |
| palustris | 850 | June, 1945 | Newark, Del. | A. J. Mix |
| | 801 | June, 1945 | Newark, Del. | A. J. Mix |
| prinoides | 865 | May, 1946 | Vinland, Ks. | A. J. Mix |
| | 866 | May, 1946 | Vinland, Ks. | A. J. Mix |
| velutina | 436 | June 8, 1937 | Camdenton, Mo. | A. J. Mix |
| | 851 | June, 1945 | Newark, Del. | A. J. Mix |
| virginiana | 380 | May 18, 1936 | Princess Anne County, Va. | H. T. Cook |
| | 379 | May 18, 1936 | Princess Anne County, Va. | H. T. Cook |

various nitrogen sources in agar and to compare growth on agar with that observed in liquid culture by Mix (1952).

Robbins (1937), Steinberg (1939, 1950), and others have classified fungi according to their ability to utilize different sources of nitrogen. Robbins' classification is as follows: (1) fungi able to utilize atmospheric nitrogen, nitrate nitrogen, ammonium nitrogen, and organic nitrogen; (2) fungi able to utilize nitrate nitrogen, ammonium nitrogen, and organic nitrogen but unable to utilize atmospheric nitrogen; (3) fungi able to utilize ammonium and organic nitrogen but unable to utilize atmospheric or nitrate nitrogen; (4) fungi which are able to utilize only organic nitrogen and unable to utilize atmospheric, nitrate, or ammonium nitrogen.

Taphrina caerulescens falls in the second group as to nitrogen utilization; however, little is known as to how well it utilizes different compounds. In this study an attempt is made to compare the growth-variations on different sources of nitrogen; to compare different host forms and different isolates of the same host forms with each other; and to observe variations in amount of growth in liquid and agar culture.

The sources of nitrogen (except for amino acids) were used in nitrogen concentration equivalent to that of two grams $KNO_3$ per liter. In the case of peptone the exact nitrogen content is not known. The concentration used was two grams per liter. The amino acids were used at one half of their nitrogen equivalent (Table II).

TABLE II

MOLECULAR WEIGHT OF NITROGEN SOURCES

WITH EQUIVALENT CONCENTRATION OF NITROGEN

| | Nitrogen Source | Molecular Weight | Amt.=2 gm $KNO_3$/L |
|---|---|---|---|
| 1 | Ammonium acetate | 77 | 1.5 |
| 2 | Ammonium chloride | 53 | 1.1 |
| 3 | Ammonium citrate | 243 | 1.6 |
| 4 | Ammonium nitrate | 80 | .80 |
| 5 | Ammonium oxalate | 142 | 1.4 |
| 6 | Ammonium phosphate | 115 | 2.3 |
| 7 | Ammonium sulphate | 132 | 1.3 |
| 8 | Ammonium tartrate | 184 | 1.8 |
| 9 | Sodium nitrate | 85 | 1.4 |
| 10 | Magnesium nitrate | 256 | 2.6 |
| 11 | Calcium nitrate | 164 | 2.4 |
| 12 | Potassium nitrate | 101 | 2.0 |
| 13 | Peptone | -- | 2.0 |
| 14 | Urea | 60 | 1.2 |
| 15 | dl Alanine* | 89 | 1.3 |
| 16 | β Alanine | 89 | .9 |
| 17 | Arginine mono HCl | 210 | 2.1 |
| 18 | l-(+)-Glutamic acid | 147 | 1.3 |
| 19 | Glycine | 75 | 1.5 |
| 20 | Histidine mono HCl | 191 | 2.2 |
| 21 | l Hydroxyproline | 131 | 1.3 |
| 22 | dl Isoleucine | 131 | 1.3 |
| 23 | dl Leucine | 131 | 1.5 |
| 24 | l Cysteine HCl | 262 | 1.6 |
| 25 | dl Methionine | 169 | 1.5 |
| 26 | dl β Phenylalanine | 165 | 1.7 |
| 27 | dl Proline | 115 | 1.2 |
| 28 | dl Serine | 105 | 1.1 |
| 29 | dl Threonine | 119 | 1.3 |
| 30 | dl Valine | | 1.2 |
| 31 | Asparagine | | 2.0 |
| 32 | dl Aspartic acid | | 1.3 |

*Amino acids at one-half the nitrogen equivalent.

The basal medium used consisted of the following:

| | |
|---|---|
| $KH_2PO_4$ | 2.75 grams |
| $MgSO_4$ | 1.25 grams |
| Dextrose | 20 grams |
| Agar | 20 grams |
| Thiamine (when added) | 100 micrograms per liter |

Enough distilled and demineralized water added to equal one liter

Twenty-five cubic centimeters of agar medium were placed in 125 cubic centimeters Erlenmeyer flasks. This volume was found to afford the greatest surface area for growth obtainable in flasks of this size. After autoclaving the flasks were left for several days to check for possible contamination. Each isolate was transferred to the flasks by the stab method; each flask received five transfers. Four flasks were used for each isolate, two without and two with thiamine hydrochloride.

The cultures were grown at room temperature for 21 days, which was sufficient for maximum growth to occur. Also it was felt that this period was long enough to minimize possible differences due to amount of inoculum and impurities included in the transfer.

The stock cultures were maintained on potato dextrose agar. When transfers had grown sufficiently they were placed at 5° C in order to retard their growth until ready for use.

The formula used for potato dextrose agar is as follows:

| | |
|---|---|
| Potatoes | 210 grams |
| Dextrose | 30 grams |
| Agar | 45 grams |
| Water (distilled) | 1500 milliliters |

The potatoes were washed and sliced but not peeled. The slices were cooked until soft. The liquid was strained through cheese cloth. Care was taken to not cook the potatoes until mushy as this made straining difficult and the medium cloudy. The dextrose and agar were added and enough distilled water to bring the volume up to 1500 milliliters.

Glassware used in this experiment was Pyrex, which was washed with "Laboratory Calgonite" and rinsed in tap water, then stored until ready for use. Before use it was again rinsed in tap water and finally in distilled-demineralized water. Only C.P. grade chemicals and Difco granulated agar were used. A Barnstead Bantam Demineralizer was used to further purify the water after distillation. The demineralized water had a specific resistance of about 157,500 ohms as measured by a Barnstead Purity Meter. Sterilization was in an autoclave usually at 12 pounds pressure for twenty minutes. Shorter time periods were used in the case of greater hydrogen-ion concentration. The initial hydrogen-ion concentration was taken after the media was autoclaved. Determinations were made by means of Beckman, Model G or Model H, pH meters.

The amount of growth was rated by estimating the diameter-size of the colony at the end of the growth period.

If the colony was close to 15 millimeters in diameter it was given ++++ rating (very good growth); near ten millimeters received +++ rating (good growth); near five millimeters received ++ rating (average growth); colonies one millimeter in diameter received + rating (below average growth). If the growth was less than one millimeter in diameter it was rated as T (trace); and no growth was rated as 0. The control basis for average growth was the amount of growth which occurred on potato dextrose agar for the growth period. A card was prepared with holes in it of the above sizes (15, 10, 5 and 1 millimeters). Because of the translucence of the medium, the flasks could be set on the card and the size of the colony easily estimated. The results obtained in these experiments appear in Tables III to XXVIII.

TABLE III

GROWTH OF T. CAERULESCENS ISOLATE 398

FROM Q. ALBA ON VARIOUS SOURCES OF NITROGEN

| | Medium | Initial pH | Final pH | Rating of Growth Without Thiamine | Rating of Growth With Thiamine |
|---|---|---|---|---|---|
| 1 | Ammonium acetate | 6.3 | 6.3 | T | T |
| 2 | Ammonium chloride | 4.3 | 3.1 | ++ | +++ |
| 3 | Ammonium citrate | 4.5 | 4.2 | ++ | ++ |
| 4 | Ammonium nitrate | 4.6 | 3.3 | ++ | +++ |
| 5 | Ammonium oxalate | 5.0 | 3.2 | ++ | +++ |
| 6 | Ammonium phosphate | 4.4 | 3.1 | + | ++ |
| 7 | Ammonium sulphate | 4.6 | 2.8 | + | ++ |
| 8 | Ammonium tartrate | 4.9 | 4.3 | ++ | ++ |
| 9 | Sodium nitrate | 4.6 | 4.6 | ++ | ++ |
| 10 | Magnesium nitrate | 4.5 | 4.8 | + | ++ |
| 11 | Calcium nitrate | 4.2 | 4.5 | + | ++ |
| 12 | Potassium nitrate | 4.6 | 5.0 | ++ | ++ |
| 13 | Peptone | 4.8 | 4.8 | ++ | +++ |
| 14 | Urea | 6.4 | 7.0 | + | + |
| 15 | dl Alanine | 4.6 | 5.0 | + | + |
| 16 | β Alanine | 4.75 | 4.85 | 0 | 0 |
| 17 | Arginine mono HCl | 4.6 | 3.8 | ++ | +++ |
| 18 | l-(+)-Glutamic acid | 6.40 | 6.90 | ++ | ++ |
| 19 | Glycine | 4.70 | 5.05 | + | ++ |
| 20 | Histidine mono HCl | 4.40 | 4.10 | ++ | ++ |
| 21 | l Hydroxyproline | 4.80 | 4.90 | + | + |
| 22 | dl Isoleucine | 4.70 | 4.85 | + | + |
| 23 | dl Leucine | 4.80 | 3.75 | + | + |
| 24 | l Cysteine HCl | 4.85 | 4.60 | + | + |
| 25 | dl Methionine | 4.80 | 4.50 | + | ++ |
| 26 | dl β Phenylalanine | 4.7 | 4.4 | + | ++ |
| 27 | dl Proline | 4.70 | 5.00 | ++ | +++ |
| 28 | dl Serine | 4.60 | 4.80 | + | + |
| 29 | dl Threonine | 4.60 | 4.75 | + | + |
| 30 | dl Valine | 4.75 | 4.30 | + | + |
| 31 | Asparagine | 4.60 | 5.55 | + | ++++ |
| 32 | dl Aspartic acid | 6.30 | 6.70 | + | ++ |
| 33 | P.G.A. | | | ++ | ++ |

TABLE IV

GROWTH OF T. CAERULESCENS ISOLATE 399

FROM Q. ALBA ON VARIOUS SOURCES OF NITROGEN

| | Medium | Initial pH | Final pH | Rating of Growth Without Thiamine | Rating of Growth With Thiamine |
|---|---|---|---|---|---|
| 1 | Ammonium acetate | 6.3 | 6.3 | T | T |
| 2 | Ammonium chloride | 4.3 | 3.1 | ++ | +++ |
| 3 | Ammonium citrate | 4.5 | 4.3 | ++ | ++ |
| 4 | Ammonium nitrate | 4.6 | 3.3 | ++ | +++ |
| 5 | Ammonium oxalate | 5.0 | 3.5 | ++ | +++ |
| 6 | Ammonium phosphate | 4.4 | 2.6 | ++ | +++ |
| 7 | Ammonium sulphate | 4.6 | 3.0 | ++ | ++ |
| 8 | Ammonium tartrate | 4.9 | 4.1 | ++ | ++ |
| 9 | Sodium nitrate | 4.6 | 5.6 | ++ | +++ |
| 10 | Magnesium nitrate | 4.5 | 3.9 | + | ++ |
| 11 | Calcium nitrate | 4.2 | 5.0 | + | ++ |
| 12 | Potassium nitrate | 4.6 | 5.4 | ++ | +++ |
| 13 | Peptone | 4.8 | 4.8 | ++ | +++ |
| 14 | Urea | 6.4 | 7.0 | + | ++ |
| 15 | dl Alanine | 4.6 | 5.0 | + | + |
| 16 | β Alanine | 4.75 | 4.85 | T | T |
| 17 | Arginine mono HCl | 4.6 | 3.9 | ++ | +++ |
| 18 | l-(+)-Glutamic acid | 6.40 | 6.80 | + | +++ |
| 19 | Glycine | 4.70 | 5.05 | + | ++ |
| 20 | Histidine mono HCl | 4.40 | 4.20 | ++ | ++ |
| 21 | l Hydroxyproline | 4.80 | 4.90 | + | + |
| 22 | dl Isoleucine | 4.70 | 4.90 | + | + |
| 23 | dl Leucine | 4.80 | 3.85 | + | + |
| 24 | l Cysteine HCl | 4.85 | 4.50 | + | + |
| 25 | dl Methionine | 4.80 | 4.60 | + | ++ |
| 26 | dl β Phenylalanine | 4.7 | 4.4 | + | ++ |
| 27 | dl Proline | 4.70 | 5.00 | ++ | +++ |
| 28 | dl Serine | 4.60 | 4.85 | + | + |
| 29 | dl Threonine | 4.60 | 4.75 | + | + |
| 30 | dl Valine | 4.75 | 4.30 | + | + |
| 31 | Asparagine | 4.60 | 5.55 | + | ++++ |
| 32 | dl Aspartic acid | 6.30 | 6.70 | + | ++ |
| 33 | P.G.A. | | | ++ | ++ |

TABLE V

GROWTH OF *T. CAERULESCENS* ISOLATE 375

FROM *Q. BUSHII* ON VARIOUS SOURCES OF NITROGEN

| | Medium | Initial pH | Final pH | Rating of Growth Without Thiamine | Rating of Growth With Thiamine |
|---|---|---|---|---|---|
| 1 | Ammonium acetate | 6.3 | 6.3 | + | + |
| 2 | Ammonium chloride | 4.3 | 2.7 | ++ | +++ |
| 3 | Ammonium citrate | 4.5 | 4.0 | ++ | ++ |
| 4 | Ammonium nitrate | 4.6 | 5.1 | ++ | +++ |
| 5 | Ammonium oxalate | 5.0 | 4.5 | ++ | +++ |
| 6 | Ammonium phosphate | 4.4 | 2.6 | ++ | +++ |
| 7 | Ammonium sulphate | 4.6 | 2.6 | ++ | +++ |
| 8 | Ammonium tartrate | 4.9 | 3.5 | ++ | +++ |
| 9 | Sodium nitrate | 4.6 | 6.4 | ++ | +++ |
| 10 | Magnesium nitrate | 4.5 | 6.4 | ++ | +++ |
| 11 | Calcium nitrate | 4.2 | 5.9 | ++ | +++ |
| 12 | Potassium nitrate | 4.6 | 6.5 | ++ | +++ |
| 13 | Peptone | 4.8 | 4.9 | ++ | +++ |
| 14 | Urea | 6.4 | 6.9 | + | ++ |
| 15 | dl Alanine | 4.6 | 4.8 | ++ | ++ |
| 16 | β Alanine | 4.75 | 4.85 | T | T |
| 17 | Arginine mono HCl | 4.6 | 4.0 | ++ | +++ |
| 18 | l-(+)-Glutamic acid | 6.40 | 6.90 | ++ | +++ |
| 19 | Glycine | 4.70 | 4.65 | ++ | ++ |
| 20 | Histidine mono HCl | 4.40 | 4.25 | ++ | ++ |
| 21 | l Hydroxyproline | 4.80 | 4.70 | + | + |
| 22 | dl Isoleucine | 4.70 | 4.75 | + | + |
| 23 | dl Leucine | 4.80 | 3.40 | + | + |
| 24 | l Cysteine HCl | 4.85 | 4.80 | + | + |
| 25 | dl Methionine | 4.80 | 4.30 | + | ++ |
| 26 | dl β Phenylalanine | 4.7 | 4.4 | + | ++ |
| 27 | dl Proline | 4.70 | 5.10 | ++ | +++ |
| 28 | dl Serine | 4.60 | 4.70 | + | ++ |
| 29 | dl Threonine | 4.60 | 4.70 | + | + |
| 30 | dl Valine | 4.75 | 3.75 | + | ++ |
| 31 | Asparagine | 4.60 | 5.60 | ++ | ++++ |
| 32 | dl Aspartic Acid | 6.30 | 6.70 | ++ | ++ |
| 33 | P.G.A. | | | ++ | ++ |

TABLE VI

GROWTH OF T. CAERULESCENS ISOLATE 384

FROM Q. BUSHII ON VARIOUS SOURCES OF NITROGEN

| | Medium | Initial pH | Final pH | Rating of Growth Without Thiamine | With Thiamine |
|---|---|---|---|---|---|
| 1 | Ammonium acetate | 6.3 | 6.3 | + | + |
| 2 | Ammonium chloride | 4.3 | 2.7 | ++ | +++ |
| 3 | Ammonium citrate | 4.5 | 3.8 | ++ | ++ |
| 4 | Ammonium nitrate | 4.6 | 5.3 | ++ | +++ |
| 5 | Ammonium oxalate | 5.0 | 3.6 | ++ | +++ |
| 6 | Ammonium phosphate | 4.4 | 2.6 | ++ | +++ |
| 7 | Ammonium sulphate | 4.6 | 2.6 | ++ | +++ |
| 8 | Ammonium tartrate | 4.9 | 3.7 | ++ | +++ |
| 9 | Sodium nitrate | 4.6 | 6.4 | ++ | +++ |
| 10 | Magnesium nitrate | 4.5 | 6.6 | ++ | ++++ |
| 11 | Calcium nitrate | 4.2 | 5.8 | ++ | +++ |
| 12 | Potassium nitrate | 4.6 | 6.5 | ++ | +++ |
| 13 | Peptone | 4.8 | 4.8 | ++ | +++ |
| 14 | Urea | 6.4 | 6.9 | + | ++ |
| 15 | dl Alanine | 4.6 | 4.9 | ++ | ++ |
| 16 | β Alanine | 4.55 | 4.85 | T | T |
| 17 | Arginine mono HCl | 4.6 | 4.1 | ++ | +++ |
| 18 | l-(+)-Glutamic acid | 6.40 | 6.85 | ++ | +++ |
| 19 | Glycine | 4.70 | 4.55 | ++ | ++ |
| 20 | Histidine mono HCl | 4.40 | 4.35 | ++ | ++ |
| 21 | l Hydroxyproline | 4.80 | 4.60 | + | ++ |
| 22 | dl Isoleucine | 4.70 | 4.85 | + | + |
| 23 | dl Leucine | 4.80 | 3.45 | + | ++ |
| 24 | l Cysteine HCl | 4.85 | 4.75 | + | + |
| 25 | dl Methionine | 4.80 | 4.40 | + | ++ |
| 26 | dl β Phenylalanine | 4.7 | 4.4 | ++ | ++ |
| 27 | dl Proline | 4.70 | 5.10 | ++ | ++++ |
| 28 | dl Serine | 4.60 | 4.75 | + | ++ |
| 29 | dl Threonine | 4.60 | 4.60 | + | + |
| 30 | dl Valine | 4.75 | 4.00 | + | ++ |
| 31 | Asparagine | 4.60 | 5.30 | ++ | ++++ |
| 32 | dl Aspartic acid | 6.30 | 6.65 | ++ | ++ |
| 33 | P.G.A. | | | ++ | ++ |

TABLE VII

GROWTH OF T. CAERULESCENS ISOLATE 348

FROM Q. COCCINEA ON VARIOUS SOURCES OF NITROGEN

| | Medium | Initial pH | Final pH | Rating of Growth Without Thiamine | Rating of Growth With Thiamine |
|---|---|---|---|---|---|
| 1 | Ammonium acetate | 6.3 | 6.4 | ++ | ++ |
| 2 | Ammonium chloride | 4.3 | 3.0 | +++ | +++ |
| 3 | Ammonium citrate | 4.5 | 4.1 | ++ | ++ |
| 4 | Ammonium nitrate | 4.6 | 3.2 | ++ | +++ |
| 5 | Ammonium oxalate | 5.0 | 3.6 | ++ | +++ |
| 6 | Ammonium phosphate | 4.4 | 3.0 | ++ | +++ |
| 7 | Ammonium sulphate | 4.6 | 3.2 | ++ | +++ |
| 8 | Ammonium tartrate | 4.9 | 4.4 | + | ++ |
| 9 | Sodium nitrate | 4.6 | 5.4 | ++ | ++ |
| 10 | Magnesium nitrate | 4.5 | 5.1 | + | ++ |
| 11 | Calcium nitrate | 4.2 | 4.9 | ++ | ++ |
| 12 | Potassium nitrate | 4.6 | 5.7 | + | +++ |
| 13 | Peptone | 4.8 | 5.0 | ++ | +++ |
| 14 | Urea | 6.4 | 7.3 | + | + |
| 15 | dl Alanine | 4.6 | 4.9 | + | + |
| 16 | β Alanine | 4.55 | 4.90 | + | + |
| 17 | Arginine mono HCl | 4.6 | 4.2 | ++ | +++ |
| 18 | l-(+)-Glutamic acid | 6.40 | 6.90 | + | +++ |
| 19 | Glycine | 4.70 | 4.90 | + | + |
| 20 | Histidine mono HCl | 4.40 | 4.75 | ++ | ++ |
| 21 | l Hydroxyproline | 4.80 | 5.00 | + | + |
| 22 | dl Isoleucine | 4.70 | 4.75 | + | ++ |
| 23 | dl Leucine | 4.80 | 3.80 | + | + |
| 24 | l Cysteine HCl | 4.85 | 4.80 | 0 | 0 |
| 25 | dl Methionine | 4.80 | 4.40 | + | ++ |
| 26 | dl β Phenylalanine | 4.7 | 4.1 | ++ | ++ |
| 27 | dl Proline | 4.70 | 5.20 | + | +++ |
| 28 | dl Serine | 4.60 | 4.80 | + | + |
| 29 | dl Threonine | 4.60 | 4.75 | + | + |
| 30 | dl Valine | 4.75 | 4.55 | + | ++ |
| 31 | Asparagine | 4.60 | 5.30 | + | +++ |
| 32 | dl Aspartic acid | 6.30 | 6.40 | + | + |
| 33 | P.G.A. | | | ++ | ++ |

TABLE VIII

GROWTH OF T. CAERULESCENS ISOLATE 790

FROM Q. COCCINEA ON VARIOUS SOURCES OF NITROGEN

| | Medium | Initial pH | Final pH | Rating of Growth Without Thiamine | With Thiamine |
|---|---|---|---|---|---|
| 1 | Ammonium acetate | 6.3 | 6.3 | T | T |
| 2 | Ammonium chloride | 4.3 | 2.6 | ++ | +++ |
| 3 | Ammonium citrate | 4.5 | 3.6 | ++ | ++ |
| 4 | Ammonium nitrate | 4.6 | 4.0 | ++ | +++ |
| 5 | Ammonium oxalate | 5.0 | 3.0 | +++ | +++ |
| 6 | Ammonium phosphate | 4.4 | 2.6 | ++ | +++ |
| 7 | Ammonium sulphate | 4.6 | 2.6 | ++ | +++ |
| 8 | Ammonium tartrate | 4.9 | 3.5 | ++ | +++ |
| 9 | Sodium nitrate | 4.6 | 6.4 | ++ | +++ |
| 10 | Magnesium nitrate | 4.5 | 6.6 | ++ | +++ |
| 11 | Calcium nitrate | 4.2 | 5.8 | ++ | +++ |
| 12 | Potassium nitrate | 4.6 | 6.6 | ++ | ++++ |
| 13 | Peptone | 4.8 | 4.7 | ++ | +++ |
| 14 | Urea | 6.4 | 7.0 | + | ++ |
| 15 | dl Alanine | 4.6 | 4.8 | + | + |
| 16 | β Alanine | 4.75 | 4.85 | T | T |
| 17 | Arginine mono HCl | 4.6 | 4.1 | ++ | +++ |
| 18 | l-(+)-Glutamic acid | 6.40 | 6.95 | ++ | +++ |
| 19 | Glycine | 4.70 | 4.65 | ++ | ++ |
| 20 | Histidine mono HCl | 4.40 | 4.20 | ++ | ++ |
| 21 | l Hydroxyproline | 4.80 | 4.70 | + | + |
| 22 | dl Isoleucine | 4.70 | 4.70 | ++ | ++ |
| 23 | dl Leucine | 4.80 | 3.20 | + | + |
| 24 | l Cysteine HCl | 4.85 | 3.85 | ++ | ++ |
| 25 | dl Methionine | 4.80 | 4.25 | ++ | ++ |
| 26 | dl β Phenylalanine | 4.7 | 4.5 | ++ | ++ |
| 27 | dl Proline | 4.70 | 5.00 | + | +++ |
| 28 | dl Serine | 4.60 | 4.65 | + | ++ |
| 29 | dl Threonine | 4.60 | 4.80 | + | + |
| 30 | dl Valine | 4.75 | 3.85 | + | ++ |
| 31 | Asparagine | 4.60 | 5.50 | ++ | ++++ |
| 32 | dl Aspartic acid | 6.30 | 6.65 | ++ | ++ |
| 33 | P.G.A. | | | ++ | ++ |

TABLE IX

GROWTH OF T. CAERULESCENS ISOLATE 376

FROM Q. ILICIFOLIA ON VARIOUS SOURCES OF NITROGEN

| | Medium | Initial pH | Final pH | Rating of Growth Without Thiamine | Rating of Growth With Thiamine |
|---|---|---|---|---|---|
| 1 | Ammonium acetate | 6.3 | 6.3 | T | T |
| 2 | Ammonium chloride | 4.3 | 2.6 | +++ | +++ |
| 3 | Ammonium citrate | 4.5 | 3.7 | ++ | +++ |
| 4 | Ammonium nitrate | 4.6 | 4.9 | ++ | +++ |
| 5 | Ammonium oxalate | 5.0 | 3.1 | +++ | +++ |
| 6 | Ammonium phosphate | 4.4 | 2.6 | ++ | +++ |
| 7 | Ammonium sulphate | 4.6 | 2.5 | ++ | +++ |
| 8 | Ammonium tartrate | 4.9 | 3.4 | ++ | +++ |
| 9 | Sodium nitrate | 4.6 | 5.0 | ++ | ++ |
| 10 | Magnesium nitrate | 4.5 | 3.4 | ++ | ++ |
| 11 | Calcium nitrate | 4.2 | 4.6 | ++ | ++ |
| 12 | Potassium nitrate | 4.6 | 5.6 | ++ | ++ |
| 13 | Peptone | 4.8 | 5.0 | ++ | ++ |
| 14 | Urea | 6.4 | 7.6 | + | + |
| 15 | dl Alanine | 4.6 | 5.1 | ++ | ++ |
| 16 | β Alanine | 4.75 | 4.80 | T | T |
| 17 | Arginine mono HCl | 4.6 | 4.0 | ++ | +++ |
| 18 | l-(+)-Glutamic acid | 6.40 | 6.80 | ++ | +++ |
| 19 | Glycine | 4.70 | 5.05 | + | + |
| 20 | Histidine mono HCl | 4.40 | 4.20 | + | ++ |
| 21 | l Hydroxyproline | 4.80 | 4.85 | + | ++ |
| 22 | dl Isoleucine | 4.70 | 4.95 | ++ | ++ |
| 23 | dl Leucine | 4.80 | 3.40 | ++ | ++ |
| 24 | l Cysteine HCl | 4.85 | 4.65 | ++ | ++ |
| 25 | dl Methionine | 4.80 | 4.40 | ++ | ++ |
| 26 | dl β Phenylalanine | 4.7 | 4.7 | ++ | +++ |
| 27 | dl Proline | 4.70 | 5.20 | ++ | ++++ |
| 28 | dl Serine | 4.60 | 5.00 | + | ++ |
| 29 | dl Threonine | 4.60 | 4.80 | + | + |
| 30 | dl Valine | 4.75 | 3.85 | + | ++ |
| 31 | Asparagine | 4.60 | 5.35 | ++ | ++++ |
| 32 | dl Aspartic acid | 6.30 | 6.55 | ++ | ++ |
| 33 | P.G.A. | | | ++ | ++ |

TABLE X

GROWTH OF *T. CAERULESCENS* ISOLATE 217

FROM *Q. ILICIFOLIA* ON VARIOUS SOURCES OF NITROGEN

| | Medium | Initial pH | Final pH | Rating of Growth Without Thiamine | Rating of Growth With Thiamine |
|---|---|---|---|---|---|
| 1 | Ammonium acetate | 6.3 | 6.3 | T | 0 |
| 2 | Ammonium chloride | 4.3 | 2.6 | ++ | +++ |
| 3 | Ammonium citrate | 4.5 | 3.8 | ++ | +++ |
| 4 | Ammonium nitrate | 4.6 | 4.6 | ++ | +++ |
| 5 | Ammonium oxalate | 5.0 | 3.2 | ++ | +++ |
| 6 | Ammonium phosphate | 4.4 | 2.6 | +++ | +++ |
| 7 | Ammonium sulphate | 4.6 | 2.5 | ++ | +++ |
| 8 | Ammonium tartrate | 4.9 | 3.4 | ++ | +++ |
| 9 | Sodium nitrate | 4.6 | 5.1 | ++ | ++ |
| 10 | Magnesium nitrate | 4.5 | 5.2 | ++ | ++ |
| 11 | Calcium nitrate | 4.2 | 4.9 | + | + |
| 12 | Potassium nitrate | 4.6 | 5.1 | ++ | ++ |
| 13 | Peptone | 4.8 | 5.0 | ++ | ++ |
| 14 | Urea | 6.4 | 7.7 | + | + |
| 15 | dl Alanine | 4.6 | 3.8 | ++ | ++ |
| 16 | β Alanine | 4.75 | 4.90 | + | + |
| 17 | Arginine mono HCl | 4.6 | 4.1 | ++ | +++ |
| 18 | l-(+)-Glutamic acid | 6.40 | 6.80 | ++ | +++ |
| 19 | Glycine | 4.70 | 5.00 | + | + |
| 20 | Histidine mono HCl | 4.40 | 4.30 | + | ++ |
| 21 | l Hydroxyproline | 4.80 | 4.90 | + | ++ |
| 22 | dl Isoleucine | 4.70 | 4.90 | ++ | ++ |
| 23 | dl Leucine | 4.80 | 3.20 | ++ | ++ |
| 24 | l Cysteine HCl | 4.85 | 4.85 | + | + |
| 25 | dl Methionine | 4.80 | 4.45 | + | ++ |
| 26 | dl β Phenylalanine | 4.7 | 4.8 | ++ | ++ |
| 27 | dl Proline | 4.70 | 5.75 | ++ | +++ |
| 28 | dl Serine | 4.60 | 5.00 | + | + |
| 29 | dl Threonine | 4.60 | 4.85 | + | + |
| 30 | dl Valine | 4.75 | 4.10 | + | ++ |
| 31 | Asparagine | 4.60 | 5.35 | ++ | ++++ |
| 32 | dl Aspartic acid | 6.30 | 6.55 | ++ | ++ |
| 33 | P.G.A. | | | ++ | ++ |

TABLE XI

GROWTH OF T. CAERULESCENS ISOLATE 252

FROM Q. LAURIFOLIA ON VARIOUS SOURCES OF NITROGEN

| | Medium | Initial pH | Final pH | Rating of Growth Without Thiamine | Rating of Growth With Thiamine |
|---|---|---|---|---|---|
| 1 | Ammonium acetate | 6.3 | 6.4 | + | ++ |
| 2 | Ammonium chloride | 4.3 | 3.3 | ++ | ++ |
| 3 | Ammonium citrate | 4.5 | 4.4 | ++ | ++ |
| 4 | Ammonium nitrate | 4.6 | 3.5 | ++ | +++ |
| 5 | Ammonium oxalate | 5.0 | 4.1 | ++ | +++ |
| 6 | Ammonium phosphate | 4.4 | 2.8 | ++ | +++ |
| 7 | Ammonium sulphate | 4.6 | 3.5 | ++ | +++ |
| 8 | Ammonium tartrate | 4.9 | 4.3 | ++ | +++ |
| 9 | Sodium nitrate | 4.6 | 5.1 | + | + |
| 10 | Magnesium nitrate | 4.5 | 4.8 | ++ | ++ |
| 11 | Calcium nitrate | 4.2 | 4.5 | ++ | ++ |
| 12 | Potassium nitrate | 4.6 | 5.0 | + | + |
| 13 | Peptone | 4.8 | 5.1 | ++ | ++ |
| 14 | Urea | 6.4 | 6.6 | + | ++ |
| 15 | dl Alanine | 4.6 | 5.0 | + | + |
| 16 | β Alanine | 4.75 | 5.05 | + | + |
| 17 | Arginine mono HCl | 4.6 | 4.2 | ++ | +++ |
| 18 | l-(+)-Glutamic acid | 6.40 | 6.50 | + | ++ |
| 19 | Glycine | 4.70 | 4.85 | + | + |
| 20 | Histidine mono HCl | 4.40 | 4.25 | + | ++ |
| 21 | l Hydroxyproline | 4.80 | 4.90 | + | + |
| 22 | dl Isoleucine | 4.70 | 4.90 | ++ | ++ |
| 23 | dl Leucine | 4.80 | 4.00 | ++ | ++ |
| 24 | l Cysteine HCl | 4.85 | 4.90 | + | + |
| 25 | dl Methionine | 4.80 | 4.75 | + | ++ |
| 26 | dl β Phenylalanine | 4.7 | 4.5 | ++ | ++ |
| 27 | dl Proline | 4.70 | 5.00 | ++ | ++ |
| 28 | dl Serine | 4.60 | 4.90 | + | + |
| 29 | dl Threonine | 4.60 | 5.05 | + | + |
| 30 | dl Valine | 4.75 | 4.50 | ++ | ++ |
| 31 | Asparagine | 4.60 | 5.25 | ++ | ++++ |
| 32 | dl Aspartic acid | 6.30 | 6.40 | + | ++ |
| 33 | P.G.A. | | | ++ | ++ |

TABLE XII

GROWTH OF *T. CAERULESCENS* ISOLATE 237

FROM *Q. LAURIFOLIA* ON VARIOUS SOURCES OF NITROGEN

| | Medium | Initial pH | Final pH | Rating of Growth Without Thiamine | With Thiamine |
|---|---|---|---|---|---|
| 1 | Ammonium acetate | 6.3 | 6.3 | ++ | ++ |
| 2 | Ammonium chloride | 4.3 | 3.0 | ++ | ++ |
| 3 | Ammonium citrate | 4.5 | 3.9 | ++ | ++ |
| 4 | Ammonium nitrate | 4.6 | 3.1 | ++ | +++ |
| 5 | Ammonium oxalate | 5.0 | 3.8 | ++ | +++ |
| 6 | Ammonium phosphate | 4.4 | 3.3 | ++ | +++ |
| 7 | Ammonium sulphate | 4.6 | 3.2 | ++ | +++ |
| 8 | Ammonium tartrate | 4.9 | 4.4 | ++ | ++ |
| 9 | Sodium nitrate | 4.6 | 6.0 | ++ | ++ |
| 10 | Magnesium nitrate | 4.5 | 6.0 | ++ | ++ |
| 11 | Calcium nitrate | 4.2 | 5.5 | ++ | +++ |
| 12 | Potassium nitrate | 4.6 | 6.0 | ++ | ++ |
| 13 | Peptone | 4.8 | 5.0 | ++ | ++ |
| 14 | Urea | 6.4 | 7.4 | + | + |
| 15 | dl Alanine | 4.6 | 5.0 | + | + |
| 16 | β Alanine | 4.75 | 4.9 | + | + |
| 17 | Arginine mono HCl | 4.6 | 4.0 | -- | +++ |
| 18 | l-(+)-Glutamic acid | 6.40 | 6.80 | ++ | +++ |
| 19 | Glycine | 4.70 | 4.80 | + | + |
| 20 | Histidine mono HCl | 4.40 | 4.60 | ++ | ++ |
| 21 | l Hydroxyproline | 4.80 | 4.80 | + | + |
| 22 | dl Isoleucine | 4.70 | 4.65 | + | ++ |
| 23 | dl Leucine | 4.80 | 3.70 | + | + |
| 24 | l Cysteine HCl | 4.85 | 4.85 | T | T |
| 25 | dl Methionine | 4.80 | 4.40 | + | + |
| 26 | dl β Phenylalanine | 4.7 | 4.5 | -- | ++ |
| 27 | dl Proline | 4.70 | 5.20 | ++ | +++ |
| 28 | dl Serine | 4.60 | 4.80 | + | + |
| 29 | dl Threonine | 4.60 | 4.70 | + | + |
| 30 | dl Valine | 4.75 | 4.20 | + | ++ |
| 31 | Asparagine | 4.60 | 5.25 | + | +++ |
| 32 | dl Aspartic acid | 6.30 | 6.40 | + | ++ |
| 33 | P.G.A. | | | ++ | ++ |

TABLE XIII

GROWTH OF T. CAERULESCENS ISOLATE 880

FROM Q. MACROCARPA ON VARIOUS SOURCES OF NITROGEN

| | Medium | Initial pH | Final pH | Rating of Growth Without Thiamine | Rating of Growth With Thiamine |
|---|---|---|---|---|---|
| 1 | Ammonium acetate | 6.3 | 6.3 | 0 | 0 |
| 2 | Ammonium chloride | 4.3 | 3.2 | ++ | ++ |
| 3 | Ammonium citrate | 4.5 | 4.1 | ++ | ++ |
| 4 | Ammonium nitrate | 4.6 | 3.6 | ++ | ++ |
| 5 | Ammonium oxalate | 5.0 | 3.8 | ++ | ++ |
| 6 | Ammonium phosphate | 4.4 | 3.2 | + | ++ |
| 7 | Ammonium sulphate | 4.6 | 3.7 | ++ | ++ |
| 8 | Ammonium tartrate | 4.9 | 4.2 | + | ++ |
| 9 | Sodium nitrate | 4.6 | 4.6 | + | + |
| 10 | Magnesium nitrate | 4.5 | 4.6 | + | ++ |
| 11 | Calcium nitrate | 4.2 | 4.2 | + | + |
| 12 | Potassium nitrate | 4.6 | 4.6 | + | + |
| 13 | Peptone | 4.8 | 4.9 | ++ | ++ |
| 14 | Urea | 6.4 | 6.7 | + | + |
| 15 | dl Alanine | 4.6 | 4.8 | T | T |
| 16 | β Alanine | 4.75 | 4.80 | 0 | T |
| 17 | Arginine mono HCl | 4.6 | 4.2 | ++ | ++ |
| 18 | l-(+)-Glutamic acid | 6.40 | 6.50 | ++ | ++ |
| 19 | Glycine | 4.70 | 4.85 | + | + |
| 20 | Histidine mono HCl | 4.40 | 4.40 | + | ++ |
| 21 | l Hydroxyproline | 4.80 | 4.90 | + | + |
| 22 | dl Isoleucine | 4.70 | 4.90 | + | + |
| 23 | dl Leucine | 4.80 | 3.60 | + | + |
| 24 | l Cysteine HCl | 4.85 | 4.80 | T | T |
| 25 | dl Methionine | 4.80 | 4.90 | T | + |
| 26 | dl β Phenylalanine | 4.7 | 4.5 | ++ | ++ |
| 27 | dl Proline | 4.70 | 4.90 | + | + |
| 28 | dl Serine | 4.60 | 4.75 | + | + |
| 29 | dl Threonine | 4.60 | 4.70 | T | T |
| 30 | dl Valine | 4.75 | 3.75 | + | ++ |
| 31 | Asparagine | 4.60 | 3.55 | + | +++ |
| 32 | dl Aspartic acid | 6.30 | 6.25 | + | + |
| 33 | P.G.A. | | | ++ | ++ |

TABLE XIV

GROWTH OF T. CAERULESCENS ISOLATE 881

FROM Q. MACROCARPA ON VARIOUS SOURCES OF NITROGEN

| | Medium | Initial pH | Final pH | Rating of Growth Without Thiamine | Rating of Growth With Thiamine |
|---|---|---|---|---|---|
| 1 | Ammonium acetate | 6.3 | 6.3 | 0 | 0 |
| 2 | Ammonium chloride | 4.3 | 2.8 | ++ | +++ |
| 3 | Ammonium citrate | 4.5 | 4.2 | ++ | ++ |
| 4 | Ammonium nitrate | 4.6 | 3.6 | ++ | ++ |
| 5 | Ammonium oxalate | 5.0 | 3.6 | ++ | ++ |
| 6 | Ammonium phosphate | 4.4 | 2.6 | ++ | +++ |
| 7 | Ammonium sulphate | 4.6 | 3.2 | + | ++ |
| 8 | Ammonium tartrate | 4.9 | 3.9 | ++ | +++ |
| 9 | Sodium nitrate | 4.6 | 4.8 | + | + |
| 10 | Magnesium nitrate | 4.5 | 4.8 | + | ++ |
| 11 | Calcium nitrate | 4.2 | 4.4 | + | + |
| 12 | Potassium nitrate | 4.6 | 4.7 | ++ | ++ |
| 13 | Peptone | 4.8 | 4.8 | + | ++ |
| 14 | Urea | 6.4 | 7.0 | + | ++ |
| 15 | dl Alanine | 4.6 | 4.8 | + | + |
| 16 | β Alanine | 4.75 | 4.80 | T | T |
| 17 | Arginine mono HCl | 4.6 | 4.5 | ++ | ++ |
| 18 | l-(+)-Glutamic acid | 6.40 | 6.55 | ++ | +++ |
| 19 | Glycine | 4.70 | 4.75 | + | + |
| 20 | Histidine mono HCl | 4.40 | 4.25 | + | ++ |
| 21 | l Hydroxyproline | 4.80 | 4.85 | + | + |
| 22 | dl Isoleucine | 4.70 | 4.90 | + | + |
| 23 | dl Leucine | 4.80 | 3.55 | + | + |
| 24 | l Cysteine HCl | 4.85 | 4.80 | T | T |
| 25 | dl Methionine | 4.80 | 4.90 | T | + |
| 26 | dl β Phenylalanine | 4.7 | 4.7 | ++ | ++ |
| 27 | dl Proline | 4.70 | 4.75 | + | + |
| 28 | dl Serine | 4.60 | 4.75 | + | + |
| 29 | dl Threonine | 4.60 | 4.65 | + | + |
| 30 | dl Valine | 4.75 | 4.20 | + | ++ |
| 31 | Asparagine | 4.60 | 3.40-3.60 | + | +++ |
| 32 | dl Aspartic acid | 6.30 | 6.30 | + | + |
| 33 | P.G.A. | | | ++ | ++ |

TABLE XV

GROWTH OF T. CAERULESCENS ISOLATE 253

FROM Q. MARILANDICA ON VARIOUS SOURCES OF NITROGEN

| Medium | Initial pH | Final pH | Rating of Growth Without Thiamine | Rating of Growth With Thiamine |
|---|---|---|---|---|
| 1 Ammonium acetate | 6.3 | 6.4 | T | T |
| 2 Ammonium chloride | 4.3 | 2.8 | +++ | +++ |
| 3 Ammonium citrate | 4.5 | 3.9 | ++ | +++ |
| 4 Ammonium nitrate | 4.6 | 5.5 | ++ | +++ |
| 5 Ammonium oxalate | 5.0 | 4.5 | ++ | +++ |
| 6 Ammonium phosphate | 4.4 | 2.5 | ++ | +++ |
| 7 Ammonium sulphate | 4.6 | 2.6 | ++ | +++ |
| 8 Ammonium tartrate | 4.9 | 3.6 | ++ | +++ |
| 9 Sodium nitrate | 4.6 | 6.4 | ++ | +++ |
| 10 Magnesium nitrate | 4.5 | 6.2 | ++ | +++ |
| 11 Calcium nitrate | 4.2 | 5.7 | ++ | ++++ |
| 12 Potassium nitrate | 4.6 | 6.3 | ++ | ++++ |
| 13 Peptone | 4.8 | 4.8 | +++ | +++ |
| 14 Urea | 6.4 | 6.4 | + | ++ |
| 15 dl Alanine | 4.6 | 4.8 | ++ | ++ |
| 16 β Alanine | 4.75 | 4.85 | + | + |
| 17 Arginine mono HCl | 4.6 | 4.2 | ++ | +++ |
| 18 l-(+)-Glutamic acid | 6.40 | 6.90 | ++ | +++ |
| 19 Glycine | 4.70 | 4.75 | + | + |
| 20 Histidine mono HCl | 4.40 | 4.50 | ++ | ++ |
| 21 l Hydroxyproline | 4.80 | 4.85 | + | + |
| 22 dl Isoleucine | 4.70 | 4.70 | + | + |
| 23 dl Leucine | 4.80 | 3.20 | ++ | ++ |
| 24 l Cysteine HCl | 4.85 | 4.80 | T | T |
| 25 dl Methionine | 4.80 | 4.30 | ++ | ++ |
| 26 dl β Phenylalanine | 4.7 | 4.3 | ++ | ++ |
| 27 dl Proline | 4.70 | 5.20 | ++ | ++++ |
| 28 dl Serine | 4.60 | 4.75 | + | + |
| 29 dl Threonine | 4.60 | 4.70 | + | + |
| 30 dl Valine | 4.75 | 4.25 | + | ++ |
| 31 Asparagine | 4.60 | 5.15 | + | +++ |
| 32 dl Aspartic acid | 6.30 | 6.40 | + | ++ |
| 33 P.G.A. | | | ++ | ++ |

TABLE XVI

GROWTH OF T. CAERULESCENS ISOLATE 322

FROM Q. MARILANDICA ON VARIOUS SOURCES OF NITROGEN

| | Medium | Initial pH | Final pH | Rating of Growth Without Thiamine | With Thiamine |
|---|---|---|---|---|---|
| 1 | Ammonium acetate | 6.3 | 6.3 | T | T |
| 2 | Ammonium chloride | 4.3 | 2.6 | +++ | +++ |
| 3 | Ammonium citrate | 4.5 | 3.9 | ++ | +++ |
| 4 | Ammonium nitrate | 4.6 | 4.7 | ++ | ++++ |
| 5 | Ammonium oxalate | 5.0 | 3.5 | ++ | +++ |
| 6 | Ammonium phosphate | 4.4 | 2.6 | ++ | +++ |
| 7 | Ammonium sulphate | 4.6 | 2.6 | ++ | +++ |
| 8 | Ammonium tartrate | 4.9 | 3.7 | ++ | ++++ |
| 9 | Sodium nitrate | 4.6 | 6.3 | ++ | +++ |
| 10 | Magnesium nitrate | 4.5 | 6.5 | ++ | +++ |
| 11 | Calcium nitrate | 4.2 | 5.8 | ++ | ++++ |
| 12 | Potassium nitrate | 4.6 | 6.5 | ++ | ++++ |
| 13 | Peptone | 4.8 | 4.8 | ++ | +++ |
| 14 | Urea | 6.4 | 6.8 | + | ++ |
| 15 | dl Alanine | 4.6 | 4.8 | ++ | ++ |
| 16 | β Alanine | 4.75 | 4.70 | T | T |
| 17 | Arginine mono HCl | 4.6 | 4.7 | ++ | ++++ |
| 18 | l-(+)-Glutamic acid | 6.40 | 7.00 | +++ | +++ |
| 19 | Glycine | 4.70 | 4.75 | ++ | ++ |
| 20 | Histidine mono HCl | 4.40 | 4.10 | ++ | ++ |
| 21 | l Hydroxyproline | 4.80 | 4.70 | + | + |
| 22 | dl Isoleucine | 4.70 | 4.85 | ++ | ++ |
| 23 | dl Leucine | 4.80 | 3.00 | ++ | ++ |
| 24 | l Cysteine HCl | 4.85 | 4.75 | ++ | + |
| 25 | dl Methionine | 4.80 | 4.20 | ++ | ++ |
| 26 | dl β Phenylalanine | 4.7 | 4.4 | ++ | ++ |
| 27 | dl Proline | 4.70 | 5.20 | ++ | ++++ |
| 28 | dl Serine | 4.60 | 4.70 | ++ | ++ |
| 29 | dl Threonine | 4.60 | 4.65 | ++ | ++ |
| 30 | dl Valine | 4.75 | 3.95 | + | ++ |
| 31 | Asparagine | 4.60 | 5.75 | ++ | ++++ |
| 32 | dl Aspartic acid | 6.30 | 6.70 | ++ | ++ |
| 33 | P.G.A. | | | ++ | ++ |

TABLE XVII

GROWTH OF *T. CAERULESCENS* ISOLATE 355

FROM *Q. MAXIMA* ON VARIOUS SOURCES OF NITROGEN

| | Medium | Initial pH | Final pH | Rating of Growth Without Thiamine | Rating of Growth With Thiamine |
|---|---|---|---|---|---|
| 1 | Ammonium acetate | 6.3 | 6.4 | + | ++ |
| 2 | Ammonium chloride | 4.3 | 2.5 | ++ | +++ |
| 3 | Ammonium citrate | 4.5 | 3.8 | ++ | +++ |
| 4 | Ammonium nitrate | 4.6 | 3.9 | ++ | ++++ |
| 5 | Ammonium oxalate | 5.0 | 3.2 | ++ | +++ |
| 6 | Ammonium phosphate | 4.4 | 2.7 | ++ | +++ |
| 7 | Ammonium sulphate | 4.6 | 2.5 | ++ | +++ |
| 8 | Ammonium tartrate | 4.9 | 3.4 | ++ | +++ |
| 9 | Sodium nitrate | 4.6 | 6.3 | ++ | +++ |
| 10 | Magnesium nitrate | 4.5 | 6.5 | ++ | +++ |
| 11 | Calcium nitrate | 4.2 | 5.9 | ++ | ++++ |
| 12 | Potassium nitrate | 4.6 | 6.5 | ++ | +++ |
| 13 | Peptone | 4.8 | 4.8 | ++ | +++ |
| 14 | Urea | 6.4 | 6.7 | ++ | ++ |
| 15 | dl Alanine | 4.6 | 4.8 | ++ | ++ |
| 16 | β Alanine | 4.55 | 4.80 | T | T |
| 17 | Arginine mono HCl | 4.6 | 4.6 | ++ | ++++ |
| 18 | l-(+)-Glutamic acid | 6.40 | 6.95 | ++ | +++ |
| 19 | Glycine | 4.70 | 4.55 | + | + |
| 20 | Histidine mono HCl | 4.40 | 4.25 | ++ | ++ |
| 21 | l Hydroxyproline | 4.80 | 4.70 | + | + |
| 22 | dl Isoleucine | 4.70 | 4.80 | + | + |
| 23 | dl Leucine | 4.80 | 3.35 | + | + |
| 24 | l Cysteine HCl | 4.85 | 4.80 | ++ | + |
| 25 | dl Methionine | 4.80 | 4.45 | ++ | ++ |
| 26 | dl β Phenylalanine | 4.7 | 4.3 | ++ | ++ |
| 27 | dl Proline | 4.70 | 5.05 | ++ | +++ |
| 28 | dl Serine | 4.60 | 4.70 | + | + |
| 29 | dl Threonine | 4.60 | 4.75 | + | + |
| 30 | dl Valine | 4.75 | 4.05 | ++ | ++ |
| 31 | Asparagine | 4.60 | 5.75 | ++ | ++++ |
| 32 | dl Aspartic acid | 6.30 | 6.60 | ++ | ++ |
| 33 | P.G.A. | | | ++ | ++ |

TABLE XVIII

GROWTH OF T. CAERULESCENS ISOLATE 767

FROM Q. MAXIMA ON VARIOUS SOURCES OF NITROGEN

| | Medium | Initial pH | Final pH | Rating of Growth Without Thiamine | With Thiamine |
|---|---|---|---|---|---|
| 1 | Ammonium acetate | 6.3 | 6.3 | T | T |
| 2 | Ammonium chloride | 4.3 | 2.6 | ++ | +++ |
| 3 | Ammonium citrate | 4.5 | 4.0 | ++ | +++ |
| 4 | Ammonium nitrate | 4.6 | 3.6 | ++ | +++ |
| 5 | Ammonium oxalate | 5.0 | 3.2 | ++ | +++ |
| 6 | Ammonium phosphate | 4.4 | 2.6 | ++ | +++ |
| 7 | Ammonium sulphate | 4.6 | 3.0 | ++ | ++ * |
| 8 | Ammonium tartrate | 4.9 | 3.8 | ++ | +++ |
| 9 | Sodium nitrate | 4.6 | 6.3 | ++ | +++ |
| 10 | Magnesium nitrate | 4.5 | 6.1 | ++ | +++ |
| 11 | Calcium nitrate | 4.2 | 5.6 | ++ | ++++ |
| 12 | Potassium nitrate | 4.6 | 6.4 | ++ | +++ |
| 13 | Peptone | 4.8 | 4.7 | ++ | +++ |
| 14 | Urea | 6.4 | 6.6 | ++ | ++ |
| 15 | dl Alanine | 4.6 | 4.6 | ++ | ++ |
| 16 | β Alanine | 4.75 | 4.80 | T | T |
| 17 | Arginine mono HCl | 4.6 | 4.3 | ++ | +++ |
| 18 | l-(+)-Glutamic acid | 6.40 | 6.90 | ++ | +++ |
| 19 | Glycine | 4.70 | 4.2 | ++ | ++ |
| 20 | Histidine mono HCl | 4.40 | 4.20 | ++ | ++ |
| 21 | l Hydroxyproline | 4.80 | 4.55 | + | + |
| 22 | dl Isoleucine | 4.70 | 4.80 | + | + |
| 23 | dl Leucine | 4.80 | 3.50 | + | + |
| 24 | l Cysteine HCl | 4.85 | 4.60 | ++ | + |
| 25 | dl Methionine | 4.80 | 4.40 | ++ | ++ |
| 26 | dl β Phenylalanine | 4.7 | 4.3 | ++ | ++ |
| 27 | dl Proline | 4.70 | 5.05 | ++ | +++ |
| 28 | dl Serine | 4.60 | 4.60 | + | + |
| 29 | dl Threonine | 4.60 | 4.70 | + | + |
| 30 | dl Valine | 4.75 | 4.00 | ++ | ++ |
| 31 | Asparagine | 4.60 | 5.65 | ++ | ++++ |
| 32 | dl Aspartic acid | 6.30 | 6.55 | ++ | ++ |
| 33 | P.G.A. | | | ++ | ++ |

*No thiamine added.

TABLE XIX

GROWTH OF *T. CAERULESCENS* ISOLATE 324

FROM *Q. NIGRA* ON VARIOUS SOURCES OF NITROGEN

| | Medium | Initial pH | Final pH | Rating of Growth Without Thiamine | Rating of Growth With Thiamine |
|---|---|---|---|---|---|
| 1 | Ammonium acetate | 6.3 | 6.3 | ++ | ++ |
| 2 | Ammonium chloride | 4.3 | 2.5 | ++ | +++ |
| 3 | Ammonium citrate | 4.5 | 4.3 | ++ | ++ |
| 4 | Ammonium nitrate | 4.6 | 3.6 | ++ | +++ |
| 5 | Ammonium oxalate | 5.0 | 4.0 | ++ | +++ |
| 6 | Ammonium phosphate | 4.4 | 3.3 | ++ | +++ |
| 7 | Ammonium sulphate | 4.6 | 2.9 | +++ | +++ |
| 8 | Ammonium tartrate | 4.9 | 4.1 | ++ | +++ |
| 9 | Sodium nitrate | 4.6 | 5.8 | ++ | ++ |
| 10 | Magnesium nitrate | 4.5 | 5.9 | + | ++ |
| 11 | Calcium nitrate | 4.2 | 4.9 | ++ | +++ |
| 12 | Potassium nitrate | 4.6 | 5.8 | ++ | ++ |
| 13 | Peptone | 4.8 | 5.0 | ++ | +++ |
| 14 | Urea | 6.4 | 6.6 | ++ | ++ |
| 15 | dl Alanine | 4.6 | 5.0 | ++ | ++ |
| 16 | β Alanine | 4.75 | 5.0 | + | + |
| 17 | Arginine mono HCl | 4.6 | 4.2 | ++ | +++ |
| 18 | l-(+)-Glutamic acid | 6.40 | 6.50 | ++ | ++ |
| 19 | Glycine | 4.70 | 4.95 | ++ | ++ |
| 20 | Histidine mono HCl | 4.40 | 4.45 | ++ | ++ |
| 21 | l Hydroxyproline | 4.80 | 4.95 | + | + |
| 22 | dl Isoleucine | 4.70 | 5.00 | + | + |
| 23 | dl Leucine | 4.80 | 4.05 | ++ | ++ |
| 24 | l Cysteine HCl | 4.85 | 5.10 | T | T |
| 25 | dl Methionine | 4.80 | 4.75 | ++ | ++ |
| 26 | dl β Phenylalanine | 4.7 | 4.6 | ++ | ++ |
| 27 | dl Proline | 4.70 | 4.90 | + | + |
| 28 | dl Serine | 4.60 | 4.80 | + | + |
| 29 | dl Threonine | 4.60 | 4.90 | + | + |
| 30 | dl Valine | 4.75 | 4.80 | ++ | ++ |
| 31 | Asparagine | 4.60 | 5.80 | ++ | +++ |
| 32 | dl Aspartic acid | 6.30 | 6.45 | + | ++ |
| 33 | P.G.A. | | | ++ | ++ |

TABLE XX

GROWTH OF T. CAERULESCENS ISOLATE 361

FROM Q. NIGRA ON VARIOUS SOURCES OF NITROGEN

| Medium | Initial pH | Final pH | Rating of Growth Without Thiamine | Rating of Growth With Thiamine |
|---|---|---|---|---|
| 1 Ammonium acetate | 6.3 | 6.4 | ++ | ++ |
| 2 Ammonium chloride | 4.3 | 3.3 | ++ | ++ |
| 3 Ammonium citrate | 4.5 | 4.4 | ++ | ++ |
| 4 Ammonium nitrate | 4.6 | 3.5 | ++ | +++ |
| 5 Ammonium oxalate | 5.0 | 4.0 | ++ | +++ |
| 6 Ammonium phosphate | 4.4 | 3.0 | ++ | +++ |
| 7 Ammonium sulphate | 4.6 | 3.0 | ++ | +++ |
| 8 Ammonium tartrate | 4.9 | 4.1 | ++ | +++ |
| 9 Sodium nitrate | 4.6 | 5.4 | ++ | ++ |
| 10 Magnesium nitrate | 4.5 | 5.8 | ++ | ++ |
| 11 Calcium nitrate | 4.2 | 5.5 | ++ | +++ |
| 12 Potassium nitrate | 4.6 | 5.7 | ++ | ++ |
| 13 Peptone | 4.8 | 5.0 | ++ | +++ |
| 14 Urea | 6.4 | 6.6 | ++ | ++ |
| 15 dl Alanine | 4.6 | 5.0 | ++ | ++ |
| 16 β Alanine | 4.75 | 5.00 | + | + |
| 17 Arginine mono HCl | 4.6 | 5.6-4.6 | ++ | +++ |
| 18 l-(+)-Glutamic acid | 6.40 | 6.50 | + | + |
| 19 Glycine | 4.70 | 4.90 | ++ | ++ |
| 20 Histidine mono HCl | 4.40 | 4.50 | ++ | ++ |
| 21 l Hydroxyproline | 4.80 | 4.90 | + | + |
| 22 dl Isoleucine | 4.70 | 4.90 | + | + |
| 23 dl Leucine | 4.80 | 3.95 | + | + |
| 24 l Cysteine HCl | 4.85 | 5.00 | + | + |
| 25 dl Methionine | 4.80 | 4.70 | ++ | ++ |
| 26 dl β Phenylalanine | 4.7 | 4.4 | ++ | ++ |
| 27 dl Proline | 4.70 | 4.90 | + | + |
| 28 dl Serine | 4.60 | 4.80 | + | + |
| 29 dl Threonine | 4.60 | 4.85 | + | + |
| 30 dl Valine | 4.75 | 4.85 | ++ | ++ |
| 31 Asparagine | 4.60 | 5.30 | ++ | +++ |
| 32 dl Aspartic acid | 6.30 | 6.50 | + | ++ |
| 33 P.G.A. | | | ++ | ++ |

TABLE XXI

GROWTH OF T. CAERULESCENS ISOLATE 850

FROM Q. PALUSTRIS ON VARIOUS SOURCES OF NITROGEN

| | Medium | Initial pH | Final pH | Rating of Growth Without Thiamine | Rating of Growth With Thiamine |
|---|---|---|---|---|---|
| 1 | Ammonium acetate | 6.3 | 6.3 | + | + |
| 2 | Ammonium chloride | 4.3 | 2.6 | ++ | +++ |
| 3 | Ammonium citrate | 4.5 | 3.8 | ++ | +++ |
| 4 | Ammonium nitrate | 4.6 | 3.6 | ++ | +++ |
| 5 | Ammonium oxalate | 5.0 | 3.2 | ++ | +++ |
| 6 | Ammonium phosphate | 4.4 | 2.6 | ++ | +++ |
| 7 | Ammonium sulphate | 4.6 | 2.8 | ++ | +++ |
| 8 | Ammonium tartrate | 4.9 | 3.7 | ++ | +++ |
| 9 | Sodium nitrate | 4.6 | 6.3 | ++ | +++ |
| 10 | Magnesium nitrate | 4.5 | 6.4 | ++ | +++ |
| 11 | Calcium nitrate | 4.2 | 5.6 | ++ | ++++ |
| 12 | Potassium nitrate | 4.6 | 6.5 | ++ | ++++ |
| 13 | Peptone | 4.8 | 4.8 | ++ | +++ |
| 14 | Urea | 6.4 | 6.7 | + | ++ |
| 15 | dl Alanine | 4.6 | 4.8 | + | + |
| 16 | β Alanine | 4.75 | 4.75 | T | T |
| 17 | Arginine mono HCl | 4.6 | 4.1 | ++ | +++ |
| 18 | l-(+)-Glutamic acid | 6.40 | 7.00 | ++ | +++ |
| 19 | Glycine | 4.70 | 4.65 | + | + |
| 20 | Histidine mono HCl | 4.40 | 4.30 | ++ | ++ |
| 21 | l Hydroxyproline | 4.80 | 4.70 | + | + |
| 22 | dl Isoleucine | 4.70 | 4.70 | + | + |
| 23 | dl Leucine | 4.80 | 3.40 | ++ | ++ |
| 24 | l Cysteine HCl | 4.85 | 4.80 | + | + |
| 25 | dl Methionine | 4.80 | 4.40 | ++ | ++ |
| 26 | dl β Phenylalanine | 4.7 | 4.1 | ++ | ++ |
| 27 | dl Proline | 4.70 | 5.10 | ++ | ++++ |
| 28 | dl Serine | 4.60 | 4.65 | + | + |
| 29 | dl Threonine | 4.60 | 4.75 | + | + |
| 30 | dl Valine | 4.75 | 4.00 | ++ | ++ |
| 31 | Asparagine | 4.60 | 5.70 | ++ | ++++ |
| 32 | dl Aspartic acid | 6.30 | 6.60 | ++ | ++ |
| 33 | P.G.A. | | | ++ | ++ |

TABLE XXII

GROWTH OF T. CAERULESCENS ISOLATE 801

FROM Q. PALUSTRIS ON VARIOUS SOURCES OF NITROGEN

| | Medium | Initial pH | Final pH | Rating of Growth Without Thiamine | Rating of Growth With Thiamine |
|---|---|---|---|---|---|
| 1 | Ammonium acetate | 6.3 | 6.3 | T | T |
| 2 | Ammonium chloride | 4.3 | 2.5 | ++ | +++ |
| 3 | Ammonium citrate | 4.5 | 4.1 | ++ | +++ |
| 4 | Ammonium nitrate | 4.6 | 3.7 | ++ | +++ |
| 5 | Ammonium oxalate | 5.0 | 3.5 | ++ | +++ |
| 6 | Ammonium phosphate | 4.4 | 2.8 | ++ | +++ |
| 7 | Ammonium sulphate | 4.6 | 2.6 | ++ | +++ |
| 8 | Ammonium tartrate | 4.9 | 3.5 | ++ | +++ |
| 9 | Sodium nitrate | 4.6 | 6.3 | ++ | +++ |
| 10 | Magnesium nitrate | 4.5 | 6.3 | ++ | +++ |
| 11 | Calcium nitrate | 4.2 | 5.6 | ++ | +++ |
| 12 | Potassium nitrate | 4.6 | 6.3 | ++ | +++ |
| 13 | Peptone | 4.8 | 4.9 | ++ | +++ |
| 14 | Urea | 6.4 | 6.7 | + | ++ |
| 15 | dl Alanine | 4.6 | 4.9 | + | + |
| 16 | β Alanine | 4.75 | 4.7 | T | T |
| 17 | Arginine mono HCl | 4.6 | 4.5 | ++ | +++ |
| 18 | l-(+)-Glutamic acid | 6.40 | 6.95 | ++ | +++ |
| 19 | Glycine | 4.70 | 4.75 | + | + |
| 20 | Histidine mono HCl | 4.40 | 4.35 | ++ | ++ |
| 21 | l Hydroxyproline | 4.80 | 4.70 | + | + |
| 22 | dl Isoleucine | 4.70 | 4.85 | + | + |
| 23 | dl Leucine | 4.80 | 3.40 | ++ | ++ |
| 24 | l Cysteine HCl | 4.85 | 4.45 | ++ | + |
| 25 | dl Methionine | 4.80 | 4.40 | ++ | ++ |
| 26 | dl β Phenylalanine | 4.7 | 4.4 | ++ | ++ |
| 27 | dl Proline | 4.70 | 5.10 | ++ | +++ |
| 28 | dl Serine | 4.60 | 4.65 | ++ | ++ |
| 29 | dl Threonine | 4.60 | 4.70 | + | + |
| 30 | dl Valine | 4.75 | 3.95 | ++ | ++ |
| 31 | Asparagine | 4.60 | 5.70 | ++ | ++++ |
| 32 | dl Aspartic acid | 6.30 | 6.55 | ++ | ++ |
| 33 | P.G.A. | | | ++ | ++ |

TABLE XXIII

GROWTH OF T. CAERULESCENS ISOLATE 865

FROM Q. PRINOIDES ON VARIOUS SOURCES OF NITROGEN

| | Medium | Initial pH | Final pH | Rating of Growth Without Thiamine | Rating of Growth With Thiamine |
|---|---|---|---|---|---|
| 1 | Ammonium acetate | 6.3 | 6.3 | T | T |
| 2 | Ammonium chloride | 4.3 | 2.8 | ++ | +++ |
| 3 | Ammonium citrate | 4.5 | 4.2 | ++ | ++ |
| 4 | Ammonium nitrate | 4.6 | 3.7 | ++ | +++ |
| 5 | Ammonium oxalate | 5.0 | 3.5 | ++ | +++ |
| 6 | Ammonium phosphate | 4.4 | 3.4 | + | ++ |
| 7 | Ammonium sulphate | 4.6 | 3.7 | + | ++ |
| 8 | Ammonium tartrate | 4.9 | 4.1 | ++ | +++ |
| 9 | Sodium nitrate | 4.6 | 4.9 | + | + |
| 10 | Magnesium nitrate | 4.5 | 4.8 | ++ | ++ |
| 11 | Calcium nitrate | 4.2 | 4.4 | + | + |
| 12 | Potassium nitrate | 4.6 | 4.7 | + | + |
| 13 | Peptone | 4.8 | 4.8 | ++ | ++ |
| 14 | Urea | 6.4 | 6.8 | + | + |
| 15 | dl Alanine | 4.6 | 4.9 | + | + |
| 16 | β Alanine | 4.75 | 4.75 | T | T |
| 17 | Arginine mono HCl | 4.6 | 4.4 | ++ | +++ |
| 18 | l-(+)-Glutamic acid | 6.40 | 6.50 | ++ | ++ |
| 19 | Glycine | 4.70 | 4.75 | + | + |
| 20 | Histidine mono HCl | 4.40 | 4.25 | ++ | ++ |
| 21 | l Hydroxyproline | 4.80 | 4.75 | + | + |
| 22 | dl Isoleucine | 4.70 | 4.90 | + | + |
| 23 | dl Leucine | 4.80 | 3.60 | + | + |
| 24 | l Cysteine HCl | 4.85 | 4.70 | 0 | 0 |
| 25 | dl Methionine | 4.80 | 4.50 | + | + |
| 26 | dl β Phenylalanine | 4.7 | 4.7 | + | ++ |
| 27 | dl Proline | 4.70 | 4.70 | + | + |
| 28 | dl Serine | 4.60 | 4.55 | + | + |
| 29 | dl Threonine | 4.60 | 4.65 | + | + |
| 30 | dl Valine | 4.75 | 4.50 | + | ++ |
| 31 | Asparagine | 4.60 | 3.40-3.50 | + | +++ |
| 32 | dl Aspartic acid | 6.30 | 6.35 | + | ++ |
| 33 | P.G.A. | | | ++ | ++ |

TABLE XXIV

GROWTH OF T. CAERULESCENS ISOLATE 866

FROM Q. PRINOIDES ON VARIOUS SOURCES OF NITROGEN

| Medium | Initial pH | Final pH | Rating of Growth Without Thiamine | Rating of Growth With Thiamine |
|---|---|---|---|---|
| 1 Ammonium acetate | 6.3 | 6.3 | T | T |
| 2 Ammonium chloride | 4.3 | 2.9 | ++ | +++ |
| 3 Ammonium citrate | 4.5 | 4.2 | ++ | ++ |
| 4 Ammonium nitrate | 4.6 | 3.9 | ++ | ++ |
| 5 Ammonium oxalate | 5.0 | 3.5 | ++ | +++ |
| 6 Ammonium phosphate | 4.4 | 3.5 | + | ++ |
| 7 Ammonium sulphate | 4.6 | 3.5 | + | ++ |
| 8 Ammonium tartrate | 4.9 | 4.2 | ++ | +++ |
| 9 Sodium nitrate | 4.6 | 4.8 | ++ | ++ |
| 10 Magnesium nitrate | 4.5 | 4.6 | + | + |
| 11 Calcium nitrate | 4.2 | 4.4 | + | ++ |
| 12 Potassium nitrate | 4.6 | 4.7 | + | + |
| 13 Peptone | 4.8 | 4.8 | ++ | +++ |
| 14 Urea | 6.4 | 6.9 | + | + |
| 15 dl Alanine | 4.6 | 5.1 | ++ | ++ |
| 16 β Alanine | 4.75 | 4.70 | T | T |
| 17 Arginine mono HCl | 4.6 | 4.2 | + | +++ |
| 18 l-(+)-Glutamic acid | 6.40 | 6.60 | ++ | ++ |
| 19 Glycine | 4.70 | 4.75 | + | + |
| 20 Histidine mono HCl | 4.40 | 4.20 | ++ | ++ |
| 21 l Hydroxyproline | 4.80 | 4.75 | + | + |
| 22 dl Isoleucine | 4.70 | 4.85 | + | + |
| 23 dl Leucine | 4.80 | 3.50 | + | + |
| 24 l Cysteine HCl | 4.85 | 4.75 | 0 | 0 |
| 25 dl Methionine | 4.80 | 4.80 | + | + |
| 26 dl β Phenylalanine | 4.7 | 3.7 | + | ++ |
| 27 dl Proline | 4.70 | 4.80 | + | + |
| 28 dl Serine | 4.60 | 4.60 | + | + |
| 29 dl Threonine | 4.60 | 4.60 | + | + |
| 30 dl Valine | 4.75 | 4.00 | + | + |
| 31 Asparagine | 4.60 | 3.45 | + | +++ |
| 32 dl Aspartic acid | 6.30 | 6.30 | + | ++ |
| 33 P.G.A. | | | ++ | ++ |

TABLE XXV

GROWTH OF T. CAERULESCENS ISOLATE 436

FROM Q. VELUTINA ON VARIOUS SOURCES OF NITROGEN

| Medium | Initial pH | Final pH | Rating of Growth Without Thiamine | Rating of Growth With Thiamine |
|---|---|---|---|---|
| 1 Ammonium acetate | 6.3 | 6.5 | + | + |
| 2 Ammonium chloride | 4.3 | 2.6 | +++ | +++ |
| 3 Ammonium citrate | 4.5 | 3.7 | ++ | +++ |
| 4 Ammonium nitrate | 4.6 | 4.6 | ++ | +++ |
| 5 Ammonium oxalate | 5.0 | 3.2 | ++ | +++ |
| 6 Ammonium phosphate | 4.4 | 2.7 | ++ | +++ |
| 7 Ammonium sulphate | 4.6 | 2.6 | ++ | +++ |
| 8 Ammonium tartrate | 4.9 | 3.5 | ++ | +++ |
| 9 Sodium nitrate | 4.6 | 6.2 | ++ | +++ |
| 10 Magnesium nitrate | 4.5 | 6.5 | ++ | +++ |
| 11 Calcium nitrate | 4.2 | 5.8 | ++ | ++++ |
| 12 Potassium nitrate | 4.6 | 6.5 | ++ | ++++ |
| 13 Peptone | 4.8 | 4.8 | ++ | +++ |
| 14 Urea | 6.4 | 6.7 | + | ++ |
| 15 dl Alanine | 4.6 | 4.9 | ++ | ++ |
| 16 β Alanine | 4.75 | 4.75 | T | T |
| 17 Arginine mono HCl | 4.6 | 4.4 | ++ | ++++ |
| 18 l-(+)-Glutamic acid | 6.40 | 6.90 | ++ | +++ |
| 19 Glycine | 4.70 | 4.55 | ++ | ++ |
| 20 Histidine mono HCl | 4.40 | 4.05 | ++ | ++ |
| 21 l Hydroxyproline | 4.80 | 3.30 | + | + |
| 22 dl Isoleucine | 4.70 | 4.80 | ++ | ++ |
| 23 dl Leucine | 4.80 | 3.30 | + | + |
| 24 l Cysteine HCl | 4.85 | 4.80 | 0 | 0 |
| 25 dl Methionine | 4.80 | 4.10 | + | ++ |
| 26 dl β Phenylalanine | 4.7 | 3.4 | + | ++ |
| 27 dl Proline | 4.70 | 5.10 | ++ | +++ |
| 28 dl Serine | 4.60 | 4.60 | + | + |
| 29 dl Threonine | 4.60 | 4.70 | + | + |
| 30 dl Valine | 4.75 | 4.10 | ++ | ++ |
| 31 Asparagine | 4.60 | 5.85 | ++ | ++++ |
| 32 dl Aspartic acid | 6.30 | 6.65 | ++ | ++ |
| 33 P.G.A. | | | ++ | ++ |

TABLE XXVI

GROWTH OF T. CAERULESCENS ISOLATE 851

FROM Q. VELUTINA ON VARIOUS SOURCES OF NITROGEN

| Medium | Initial pH | Final pH | Rating of Growth Without Thiamine | Rating of Growth with Thiamine |
|---|---|---|---|---|
| 1 Ammonium acetate | 6.3 | 6.3 | + | + |
| 2 Ammonium chloride | 4.3 | 2.6 | ++ | +++ |
| 3 Ammonium citrate | 4.5 | 4.0 | ++ | +++ |
| 4 Ammonium nitrate | 4.6 | 3.6 | ++ | +++ |
| 5 Ammonium oxalate | 5.0 | 3.3 | ++ | +++ |
| 6 Ammonium phosphate | 4.4 | 2.9 | ++ | +++ |
| 7 Ammonium sulphate | 4.6 | 2.7 | ++ | +++ |
| 8 Ammonium tartrate | 4.9 | 3.7 | ++ | +++ |
| 9 Sodium nitrate | 4.6 | 6.2 | ++ | +++ |
| 10 Magnesium nitrate | 4.5 | 5.7 | ++ | +++ |
| 11 Calcium nitrate | 4.2 | 5.7 | ++ | ++++ |
| 12 Potassium nitrate | 4.6 | 6.3 | ++ | +++ |
| 13 Peptone | 4.8 | 4.8 | ++ | +++ |
| 14 Urea | 6.4 | 6.5 | + | + |
| 15 dl Alanine | 4.6 | 4.9 | ++ | ++ |
| 16 β Alanine | 4.75 | 4.75 | T | T |
| 17 Arginine mono HCl | 4.6 | 4.3 | ++ | +++ |
| 18 l-(+)-Glutamic acid | 6.40 | 6.80 | ++ | +++ |
| 19 Glycine | 4.70 | 4.65 | + | ++ |
| 20 Histidine mono HCl | 4.40 | 4.75 | ++ | ++ |
| 21 l Hydroxyproline | 4.80 | 3.65 | + | + |
| 22 dl Isoleucine | 4.70 | 4.80 | ++ | ++ |
| 23 dl Leucine | 4.80 | 3.45 | + | + |
| 24 l Cysteine HCl | 4.85 | 4.75 | T | T |
| 25 dl Methionine | 4.80 | 4.35 | + | ++ |
| 26 dl β Phenylalanine | 4.7 | 3.3 | + | ++ |
| 27 dl Proline | 4.70 | 5.10 | ++ | +++ |
| 28 dl Serine | 4.60 | 4.70 | + | + |
| 29 dl Threonine | 4.60 | 4.70 | + | + |
| 30 dl Valine | 4.75 | 4.00 | ++ | ++ |
| 31 Asparagine | 4.60 | 5.60 | ++ | ++++ |
| 32 dl Aspartic acid | 6.30 | 6.50 | ++ | ++ |
| 33 P.G.A. | | | ++ | ++ |

TABLE XXVII

GROWTH OF T. CAERULESCENS ISOLATE 380

FROM Q. VIRGINIANA ON VARIOUS SOURCES OF NITROGEN

| | Medium | Initial pH | Final pH | Rating of Growth Without Thiamine | With Thiamine |
|---|---|---|---|---|---|
| 1 | Ammonium acetate | 6.3 | 6.4 | ++ | ++ |
| 2 | Ammonium chloride | 4.3 | 3.2 | ++ | +++ |
| 3 | Ammonium citrate | 4.5 | 4.3 | ++ | ++ |
| 4 | Ammonium nitrate | 4.6 | 3.6 | ++ | +++ |
| 5 | Ammonium oxalate | 5.0 | 3.7 | ++ | +++ |
| 6 | Ammonium phosphate | 4.4 | 3.3 | ++ | +++ |
| 7 | Ammonium sulphate | 4.6 | 3.0 | ++ | +++ |
| 8 | Ammonium tartrate | 4.9 | 4.4 | ++ | +++ |
| 9 | Sodium nitrate | 4.6 | 5.4 | ++ | ++ |
| 10 | Magnesium nitrate | 4.5 | 5.0 | ++ | ++ |
| 11 | Calcium nitrate | 4.2 | 4.6 | ++ | +++ |
| 12 | Potassium nitrate | 4.6 | 5.8 | + | +++ |
| 13 | Peptone | 4.8 | 4.9 | ++ | +++ |
| 14 | Urea | 6.4 | 7.2 | + | + |
| 15 | dl Alanine | 4.6 | 4.8 | ++ | ++ |
| 16 | β Alanine | 4.75 | 4.70 | T | T |
| 17 | Arginine mono HCl | 4.6 | 4.1 | ++ | +++ |
| 18 | l-(+)-Glutamic acid | 6.40 | 6.80 | ++ | ++ |
| 19 | Glycine | 4.70 | 4.95 | + | ++ |
| 20 | Histidine mono HCl | 4.40 | 4.40 | ++ | ++ |
| 21 | l Hydroxyproline | 4.80 | 4.80 | + | + |
| 22 | dl Isoleucine | 4.70 | 4.85 | ++ | ++ |
| 23 | dl Leucine | 4.80 | 4.20 | ++ | ++ |
| 24 | l Cysteine HCl | 4.85 | 4.80 | 0 | 0 |
| 25 | dl Methionine | 4.80 | 4.75 | + | ++ |
| 26 | dl β Phenylalanine | 4.7 | 4.4 | + | ++ |
| 27 | dl Proline | 4.70 | 4.80 | + | + |
| 28 | dl Serine | 4.60 | 4.80 | + | + |
| 29 | dl Threonine | 4.60 | 4.70 | + | + |
| 30 | dl Valine | 4.75 | 4.70 | ++ | ++ |
| 31 | Asparagine | 4.60 | 5.65 | ++ | +++ |
| 32 | dl Aspartic acid | 6.30 | 6.50 | ++ | ++ |
| 33 | P.G.A. | | | ++ | ++ |

TABLE XXVIII

GROWTH OF T. CAERULESCENS ISOLATE 379

FROM Q. VIRGINIANA ON VARIOUS SOURCES OF NITROGEN

| | Medium | Initial pH | Final pH | Rating of Growth Without Thiamine | Rating of Growth With Thiamine |
|---|---|---|---|---|---|
| 1 | Ammonium acetate | 6.3 | 6.4 | ++ | ++ |
| 2 | Ammonium chloride | 4.3 | 3.4 | ++ | +++ |
| 3 | Ammonium citrate | 4.5 | 4.2 | ++ | ++ |
| 4 | Ammonium nitrate | 4.6 | 3.5 | ++ | +++ |
| 5 | Ammonium oxalate | 5.0 | 3.5 | ++ | +++ |
| 6 | Ammonium phosphate | 4.4 | 2.9 | ++ | +++ |
| 7 | Ammonium sulphate | 4.6 | 2.6 | ++ | +++ |
| 8 | Ammonium tartrate | 4.9 | 4.2 | ++ | +++ |
| 9 | Sodium nitrate | 4.6 | 6.1 | ++ | +++ |
| 10 | Magnesium nitrate | 4.5 | 5.9 | ++ | +++ |
| 11 | Calcium nitrate | 4.2 | 4.8 | ++ | +++ |
| 12 | Potassium nitrate | 4.6 | 6.0 | +++ | +++ |
| 13 | Peptone | 4.8 | 5.1 | ++ | +++ |
| 14 | Urea | 6.4 | 7.0 | + | + |
| 15 | dl Alanine | 4.6 | 5.0 | ++ | ++ |
| 16 | β Alanine | 4.75 | 4.75 | T | T |
| 17 | Arginine mono HCl | 4.6 | 5.5-4.7 | ++ | +++ |
| 18 | l-(+)-Glutamic acid | 6.40 | 6.80 | ++ | ++ |
| 19 | Glycine | 4.70 | 4.85 | + | + |
| 20 | Histidine mono HCl | 4.40 | 4.40 | ++ | ++ |
| 21 | l Hydroxyproline | 4.80 | 4.90 | + | + |
| 22 | dl Isoleucine | 4.70 | 4.85 | ++ | ++ |
| 23 | dl Leucine | 4.80 | 4.10 | ++ | ++ |
| 24 | l Cysteine HCl | 4.85 | 4.70 | 0 | 0 |
| 25 | dl Methionine | 4.80 | 4.70 | + | ++ |
| 26 | dl β Phenylalanine | 4.7 | 4.3 | + | ++ |
| 27 | dl Proline | 4.70 | 4.80 | + | + |
| 28 | dl Serine | 4.60 | 4.80 | + | + |
| 29 | dl Threonine | 4.60 | 4.60 | + | + |
| 30 | dl Valine | 4.75 | 4.75 | ++ | ++ |
| 31 | Asparagine | 4.60 | 5.60 | ++ | +++ |
| 32 | dl Aspartic acid | 6.30 | 6.50 | ++ | ++ |
| 33 | P.G.A. | | | ++ | ++ |

## Results

The resulting growth data were treated by analysis of variance to determine the relative effects of three areas of variation: (1) presence or absence of thiamine hydrochloride, (2) differences in media due to different nitrogen sources, and (3) differences in isolates from various Quercus species.

The analysis showed that presence or absence of thiamine hydrochloride had a significant (P less than .01) effect on the growth of Taphrina caerulescens. Of the three areas, the presence or absence of thiamine hydrochloride appeared to be the most marked contributing 54.1 per cent of the total variance of the experiment. In most cases the presence of thiamine hydrochloride in the media noticeably improved the growth.

Differences in media due to the presence of different nitrogen sources also had a significant (P less than .01) effect on the growth of T. caerulescens. However, media differences contributed only 2.4 per cent of the total variance.

In this analysis no significant differences in growth were found due to the species of Quercus from which the isolates were obtained, however differences in utilization of nitrogen were noted. (See later discussion.)

The nitrogen sources were rated by mean growth, without thiamine and with thiamine hydrochloride; also by the mean difference (Table XXIX). On the media without thiamine ammonium chloride exhibited the most growth and B alanine the least amount of growth. In the media which contained thiamine hydrochloride, asparagine promoted the most growth

TABLE XXIX

RATING OF NITROGEN SOURCES BY MEAN GROWTH AND MEAN DIFFERENCE OF THE AMOUNT OF GROWTH WITHOUT AND WITH THIAMINE

| Nitrogen Sources | Without Thiamine | | With Thiamine | | Mean Difference |
|---|---|---|---|---|---|
| | Mean | Rank | Mean | Rank | |
| Asparagine | 1.65 | 11 | 3.58 | 1 | 1.93 |
| Arginine mono HCl | 1.96 | 4 | 3.04 | 2 | 1.08 |
| Calcium nitrate | 1.73 | 10 | 2.73 | 7 | 1.00 |
| Ammonium phosphate | 1.88 | 6 | 2.85 | 5 | .97 |
| dl Proline | 1.65 | 11 | 2.62 | 8 | .97 |
| Ammonium nitrate | 2.00 | 3 | 2.96 | 3 | .96 |
| Ammonium sulphate | 1.85 | 7 | 2.77 | 6 | .92 |
| Ammonium tartrate | 1.93 | 5 | 2.85 | 5 | .92 |
| Ammonium oxalate | 2.08 | 2 | 2.92 | 4 | .84 |
| Potassium nitrate | 1.81 | 8 | 2.62 | 8 | .81 |
| Peptone | 1.96 | 4 | 2.73 | 7 | .77 |
| l-(+)-Glutamic acid | 1.88 | 6 | 2.62 | 8 | .74 |
| Magnesium nitrate | 1.73 | 10 | 2.46 | 10 | .73 |
| Ammonium chloride | 2.19 | 1 | 2.85 | 5 | .66 |
| Sodium nitrate | 1.85 | 7 | 2.35 | 12 | .50 |
| dl Valine | 1.42 | 14 | 1.88 | 16 | .46 |
| Urea | 1.15 | 18 | 1.58 | 18 | .45 |
| dl Methionine | 1.38 | 15 | 1.81 | 17 | .43 |
| Ammonium citrate | 2.00 | 3 | 2.38 | 11 | .38 |
| dl β Phenylalanine | 1.65 | 11 | 2.04 | 13 | .39 |
| dl Aspartic acid | 1.54 | 13 | 1.88 | 16 | .34 |
| Histidine mono HCl | 1.77 | 9 | 1.92 | 15 | .15 |
| dl Serine | 1.08 | 19 | 1.23 | 21 | .15 |
| l Hydroxyproline | 1.00 | 21 | 1.15 | 23 | .15 |
| Glycine | 1.31 | 17 | 1.46 | 19 | .15 |
| dl Isoleucine | 1.35 | 16 | 1.42 | 20 | .07 |
| β Alanine | .92 | 22 | .96 | 25 | .04 |
| Ammonium acetate | 1.15 | 18 | 1.19 | 22 | .04 |
| dl Leucine | 1.38 | 15 | 1.42 | 20 | .04 |
| dl Alanine | 1.58 | 12 | 1.58 | 18 | .00 |
| P.G.A. | 2.00 | 3 | 2.00 | 14 | .00 |
| dl Threonine | 1.04 | 20 | 1.04 | 24 | .00 |
| l Cysteine HCl | 1.00 | 21 | 1.85 | 26 | .15 |

and cysteine HCl the least amount of growth. There is poor correlation between the rank of growth on media without thiamine as compared to media with thiamine. The mean difference, however, shows direct correlation to the rank of growth on media with thiamine.

The results of the experimentation will be discussed under 6 main headings as follows: (1) Inorganic sources of nitrogen, (2) Amino acids as sources of nitrogen, (3) Other organic sources of nitrogen, (4) General cultural observations, (5) Comparison of host forms, and (6) Variations in amount of growth in liquid and agar culture.

Inorganic Sources of Nitrogen

The inorganic sources contained nitrate and ammonium nitrogen. With the exception of ammonium acetate, both the nitrate and ammonium nitrogen were utilized readily by all of the isolates of Taphrina caerulescens. With the amount of growth on potato dextrose agar rated as ++, the inorganic nitrogen sources were compared with potato dextrose agar. In the utilization of both the nitrate and ammonium nitrogen all inorganic sources showed more average growth than potato dextrose agar with the exception of ammonium acetate. Table XXX is a list of isolates which compares the utilization of nitrates and ammonium nitrogen as exhibited by their mean growth.

As the table shows there is some individual variation

TABLE XXX

A COMPARISON OF UTILIZATION OF NITRATES AND AMMONIUM NITROGEN BY ISOLATES OF *T. CAERULESCENS*

| *T. caerulescens* Isolates of *Quercus* Species | | Mean Growth on Nitrates | Mean Growth on Ammonium Nitrogen | Difference of the Means: More Growth on Nitrates | Difference of the Means: More Growth on Ammonium Nitrogen |
|---|---|---|---|---|---|
| alba | A | 1.90 | 1.94 | | .04 |
| | B | 2.10 | 2.12 | | .02 |
| bushii | A | 2.50 | 2.25 | .25 | |
| | B | 2.60 | 2.25 | .35 | |
| coccinea | A | 2.00 | 2.50 | | .50 |
| | B | 2.60 | 2.31 | .29 | |
| ilicifolia | A | 2.10 | 2.43 | | .33 |
| | B | 1.90 | 2.31 | | .41 |
| laurifolia | A | 1.70 | 2.25 | | .55 |
| | B | 2.20 | 2.25 | | .05 |
| macrocarpa | A | 1.30 | 2.00 | | .70 |
| | B | 1.50 | 1.87 | | .37 |
| marilandica | A | 2.70 | 2.37 | .33 | |
| | B | 2.80 | 2.75 | .05 | |
| maxima | A | 2.70 | 2.43 | .27 | |
| | B | 2.60 | 2.31 | .29 | |
| nigra | A | 2.10 | 2.37 | | .27 |
| | B | 2.20 | 2.31 | | .11 |
| palustris | A | 2.70 | 2.31 | .39 | |
| | B | 2.50 | 2.31 | .19 | |
| prinoides | A | 1.50 | 2.00 | | .50 |
| | B | 1.50 | 2.12 | | .62 |
| velutina | A | 2.70 | 2.37 | .33 | |
| | B | 2.60 | 2.31 | .29 | |
| virginiana | A | 2.20 | 2.68 | | .48 |
| | B | 2.60 | 2.68 | | .08 |
| | | | TOTAL | 3.03 | 5.03 |

among the isolates as to which of the two nitrogen sources were utilized more readily, but on the whole the difference is small and would probably come within the margin of experimental error. It is interesting to note, however, that the two isolates from Quercus coccinea utilized nitrate and ammonium nitrogen differently--Isolate A exhibited more growth on ammonium nitrogen and Isolate B showed more growth on nitrate nitrogen.

The hydrogen-ion concentration increased as the ammonium was used by the organism. In most cases there was direct correlation between the amount of growth and the increase in hydrogen-ion concentration.

The hydrogen-ion concentration decreased as the nitrate was utilized by the organisms releasing into the medium the sodium, magnesium, calcium and potassium ions.

A feature which has led many investigators to use ammonium nitrate as a source of nitrogen is the presence of both ammonium and nitrate ions in this substance. If Taphrina caerulescens were equally able to utilize both forms of nitrogen then the hydrogen-ion concentration should remain about the same as growth progresses. Some isolates apparently utilize more readily either the ammonium ion or the nitrate ion, as shown by Table XXXI.

The majority of the isolates utilized more readily ammonium nitrogen (as shown by the increase in hydrogen-ion concentration), but the isolates from Quercus bushii, Q. marilandica, and Q. ilicifolia apparently utilized the nitrate

TABLE XXXI

VARIATIONS IN HYDROGEN-ION CONCENTRATIONS OF

*T. CAERULESCENS* GROWN ON AMMONIUM NITRATE

| *T. caerulescens* Isolates of *Quercus* Species | | Initial pH | Final pH | Decrease in H-ion | Increase in H-ion |
|---|---|---|---|---|---|
| alba | A | 4.6 | 3.3 | | 1.3 |
| | B | 4.6 | 3.3 | | 1.3 |
| bushii | A | 4.6 | 5.1 | .5 | |
| | B | 4.6 | 5.3 | .7 | |
| coccinea | A | 4.6 | 3.2 | | 1.4 |
| | B | 4.6 | 4.0 | | .6 |
| ilicifolia | A | 4.6 | 4.9 | .3 | |
| | B | 4.6 | 4.6 | .0 | |
| laurifolia | A | 4.6 | 3.5 | | 1.1 |
| | B | 4.6 | 3.1 | | 1.5 |
| macrocarpa | A | 4.6 | 3.6 | | 1.0 |
| | B | 4.6 | 3.6 | | 1.0 |
| marilandica | A | 4.6 | 5.5 | | 1.1 |
| | B | 4.6 | 4.7 | | .1 |
| maxima | A | 4.6 | 3.9 | | .7 |
| | B | 4.6 | 3.6 | | 1.0 |
| nigra | A | 4.6 | 3.6 | | 1.0 |
| | B | 4.6 | 3.5 | | 1.1 |
| palustris | A | 4.6 | 3.6 | | 1.0 |
| | B | 4.6 | 3.7 | | .9 |
| prinoides | A | 4.6 | 3.7 | | .9 |
| | B | 4.6 | 3.9 | | .7 |
| velutina | A | 4.6 | 4.6 | | |
| | B | 4.6 | 3.6 | | 1.0 |
| virginiana | A | 4.6 | 3.6 | | 1.0 |
| | B | 4.6 | 3.5 | | 1.1 |

nitrogen as exhibited by the decrease in hydrogen-ion concentration. These exceptions do not follow the most common path of events in which the ammonium ion is absorbed first until exhausted; if the organism can utilize nitrate nitrogen, it is then assimilated.

Amino Acids as Sources of Nitrogen

Sixteen amino acids and asparagine were tested singly in agar culture using the procedure discussed in "Materials and Methods" (p. 27). The results are recorded in Tables III through XXVIII.

Only four amino acids showed more growth than potato dextrose agar. Arginine mono HCl exhibited the most growth of the amino acids and l cysteine HCl showed the least growth (Table XXIX). Several factors probably have accounted for the reduced growth in the amino acids. They were used at one-half their nitrogen equivalent, because of the cost involved. Each individual amino acid probably has an optimum initial hydrogen-ion concentration and a different time at which maximum growth is reached.

The changes in hydrogen-ion concentration have been found to be an indication of growth; however, due to the slight amount of growth the change in hydrogen-ion concentration was small.

Other Organic Sources of Nitrogen

Peptone and urea were used as nitrogen sources in agar culture and treated in the same manner as the previous experiments (Tables III through XXVIII).

More growth occurred on peptone than potato dextrose agar and rated well among all nitrogen sources tested. Of the 32 nitrogen sources, peptone ranked among the four highest media without thiamine and seventh in media with thiamine (Table XXIX).

The initial and final pH on peptone were nearly the same. The greatest decrease in hydrogen-ion concentration was from a pH of 4.8 to 5.1 which occurred with isolates from Quercus laurifolia and Q. virginiana. The greatest increase in hydrogen-ion concentration was pH 4.8 to 4.7 in the case of isolate B of Q. coccinea and isolate B of Q. maxima. Considerable growth occurred in all cases.

Less growth occurred with urea as a nitrogen source than potato dextrose agar. In media without and with thiamine, it ranked seventeenth among the nitrogen sources (Table XXIX). However, the initial hydrogen-ion concentration was below optimum.

In all cases except isolate A from Q. marilandica, the hydrogen-ion concentration decreased. In the case of isolate B from Q. ilicifolia the hydrogen-ion concentration changed from an initial pH of 6.4 to a final pH of 7.7 (Table X). Inspite of this considerable decrease in hydrogen-ion concentration,

there was only a small amount of growth in the medium, both without and with thiamine hydrochloride. In the case of the isolate A of Quercus marilandica the initial and final pH were the same but slightly more growth occurred.

General Cultural Observations

The color of the colony Taphrina caerulescens when grown on potato dextrose agar is usually a flesh pink. The appearance did change when grown on the nitrogen sources in this experiment. The color of the colony varied from a cream white through pink to a tan color. No study has been done regarding the pigment formation in T. caerulescens. The pigment is considered to be of a non-carotinoid nature and non-diffusible in the case of T. deformans (Lodder, 1934). Though the various isolates used in this experiment have been classified under one species some variations in pigment formation were noticed. The following observations were made:

The isolates of T. caerulescens exhibited three general schemes in its color response to the nitrogen sources on which it was grown. They are:

Scheme 1: A formation of a pink pigment in the colony on the medium without thiamine and a lighter pink on the medium with thiamine.

Scheme 2: A formation of a tan pigment in the colony on the medium without thiamine and a lighter tan on the medium with thiamine.

Scheme 3: A formation of a tan pigment in the colony on medium without thiamine and a pink pigment on the medium with thiamine.

In Table XXXII a comparison of variations in pigment formation of the isolates was made among four nitrogen sources; namely, sodium nitrate, peptone, l glutamic acid, and dl proline. Isolates A and B from each Quercus host responded by the same pigment formation on a particular source of nitrogen with the exception of isolates A and B of Q. coccinea and isolates A and B of Q. laurifolia. However, the response was quite different between the different host forms as Table XXXII shows.

In the case of calcium nitrate the rating of the colonies may be slightly high because of the flat and spreading habit of the growth of the colonies. The pigment of Taphrina caerulescens did not diffuse into the medium in any case.

Comparison of Host Forms

Variation in the utilization of nitrogen among the host forms was noted; however, no one nitrogen source in agar culture was completely refused by all isolates. In most cases a slight growth occurred.

In considering the amount of growth that actually occurred on a rating of +, ++, +++, and ++++ a comparison of the cross-sectional area as contained in each rating of growth was made (Table XXXIII).

The greatest increase in area occurs between the + and ++ ratings. By comparing the area of +, which is .78

TABLE XXXII

COMPARISON OF VARIATIONS IN PIGMENT FORMATION OF THE ISOLATES OF *T. CAERULESCENS*

| *T. caerulescens* Isolates of *Quercus* Species | | Nitrogen Sources | | | |
|---|---|---|---|---|---|
| | | Sodium Nitrate | Peptone | l Glutamic Acid | dl Proline |
| alba | A | 3*** | 2** | 2 | 2 |
| | B | 3 | 2 | 2 | 2 |
| bushii | A | 3 | 1* | 1 | 1 |
| | B | 3 | 1 | 1 | 1 |
| coccinea | A | 2 | 1 | 2 | 1 |
| | B | 3 | 2 | 1 | 1 |
| ilicifolia | A | 2 | 2 | 2 | 1 |
| | B | 2 | 2 | 2 | 1 |
| laurifolia | A | 2 | 1 | 2 | 1 |
| | B | 3 | 1 | 1 | 1 |
| macrocarpa | A | 2 | 2 | 2 | 1 |
| | B | 2 | 2 | 2 | 1 |
| marilandica | A | 2 | 1 | 1 | 1 |
| | B | 2 | 1 | 1 | 1 |
| maxima | A | 3 | 1 | 1 | 1 |
| | B | 3 | 1 | 1 | 1 |
| nigra | A | 3 | 1 | 2 | 1 |
| | B | 3 | 1 | 2 | 1 |
| palustris | A | 3 | 1 | 1 | 1 |
| | B | 3 | 1 | 1 | 1 |
| prinoides | A | 2 | 1 | 2 | 1 |
| | B | 2 | 1 | 2 | 1 |
| velutina | A | 3 | 1 | 1 | 1 |
| | B | 3 | 1 | 1 | 1 |
| virginiana | A | 2 | 2 | 2 | 2 |
| | B | 2 | 2 | 2 | 2 |

*Scheme 1: color of colony--pink without thiamine and lighter pink with thiamine.

**Scheme 2: color of colony--tan both without and with thiamine.

***Scheme 3: color of colony--tan without thiamine and pink with thiamine.

TABLE XXXIII

A COMPARISON OF CROSS-SECTIONAL AREA

CONTAINED IN EACH RATING OF GROWTH

| Rating of Growth | Cross-Sectional Area in Sq. mm | Difference in Areas Between Ratings |
|---|---|---|
| + | .78 | |
| | | . . . . . .78 : 19.6 = 25.9* |
| ++ | 19.6 | |
| | | . . . . . 19.6 : 78.6 = 4.0 |
| +++ | 78.6 | |
| | | . . . . . 78.6 : 176.9 = 2.3 |
| ++++ | 176.9 | |

*Number of times ++ is greater than +.

square millimeters, with the rating of ++, which is 19.6 square millimeters, the increase is 25.9 times. By this it was assumed that an isolate would utilize over 25 times more of the available nitrogen in order to increase its growth from + to ++. The difference between ++ and +++ increased only 4.0 times and between +++ and ++++ 2.3 times, hence less proportionate utilization of nitrogen.

The following isolates were compared according to the amount of growth on the different nitrogen sources. All isolates which showed a growth of + or less were considered as refusing or poorly utilizing that nitrogen source. If either isolate of a host showed ++ growth on a medium without or with thiamine it was considered as utilizing the nitrogen well. By assigning numbers to the nitrogen sources, the following comparison was made (Table XXXIV). The numbers that appear in the table designate those sources on which slight or no growth occurred, listed in the order of the number of refusals.

In general no two host forms followed the same pattern of growth. Isolates of Quercus macrocarpa exhibited slight or no growth on 14 of the 32 nitrogen sources while isolates of Q. maxima showed poor utilization in only one of the 32 nitrogen sources. These two cases are the extreme variations in the utilization of nitrogen.

Another comparison was made in which the best growth was considered. If an isolate grew enough to be rated as +++ or ++++ on a source of nitrogen, it was included in this comparison. The results appear in Table XXXV listed in order

TABLE XXXIV

A COMPARISON OF HOST FORMS IN THE ORDER

OF REFUSAL OR NEAR REFUSAL OF NITROGEN SOURCES

| *T. caerulescens* Isolates of *Quercus* Species | Refusal or Near Refusal of Nitrogen Sources* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| macrocarpa | 1 | 11 | 15 | 16 | 19 | 21 | 22 | 23 | 24 | 25 | 27 | 28 |
| | 29 | 32 | | | | | | | | | | |
| prinoides | 1 | 14 | 16 | 19 | 21 | 22 | 24 | 25 | 27 | 28 | 29 | |
| alba | 1 | 16 | 21 | 22 | 24 | 28 | 30 | | | | | |
| nigra | 16 | 18 | 21 | 24 | 27 | 29 | | | | | | |
| virginiana | 14 | 16 | 24 | 27 | 28 | 29 | | | | | | |
| palustris | 1 | 16 | 19 | 21 | 29 | | | | | | | |
| velutina | 1 | 16 | 24 | 29 | | | | | | | | |
| laurifolia | 21 | 24 | 28 | 29 | | | | | | | | |
| marilandica | 1 | 16 | 21 | | | | | | | | | |
| bushii | 1 | 16 | | | | | | | | | | |
| coccinea | 16 | 21 | | | | | | | | | | |
| ilicifolia | 1 | 16 | | | | | | | | | | |
| maxima | 16 | | | | | | | | | | | |

*Number 1 through 32 indicate nitrogen sources as listed on Tables III through XXVIII.

TABLE XXXV

A COMPARISON OF HOST FORMS IN THE ORDER OF BEST UTILIZATION OF NITROGEN

| *T. caerulescens* Isolates of *Quercus* Species | Best Utilization of Nitrogen Sources* |
|---|---|
| palustris | 2 3 4 5 6 7 8 9 10 11 12 13 17 18 19 27 31 |
| marilandica | 2 3 4 5 6 7 8 9 10 11 12 13 17 18 27 31 |
| maxima | 2 3 4 5 6 7 8 9 10 11 12 13 17 18 27 31 |
| bushii | 2 4 5 6 7 8 9 10 11 12 13 17 18 27 31 |
| coccinea | 2 4 5 6 7 8 9 10 11 12 13 17 18 27 31 |
| velutina | 2 3 4 5 6 7 8 9 10 11 12 13 17 27 31 |
| virginiana | 2 4 5 6 7 8 9 10 11 12 13 17 18 31 |
| ilicifolia | 2 3 4 5 6 7 8 17 18 26 27 31 |
| alba | 2 4 5 6 9 12 13 17 18 27 31 |
| laurifolia | 4 5 6 7 8 11 17 18 26 27 31 |
| nigra | 2 4 5 6 7 8 11 13 17 31 |
| prinoides | 2 4, 5 8 12 17 31 |
| macrocarpa | 6 8 18 31 |

*Number 1 through 32 indicate nitrogen sources as listed on Tables III through XXVIII.

of best utilization of nitrogen. The numbers that appear in the table designate those sources on which good growth occurred.

In considering the host forms in reference to the most utilization, there is less variation exhibited in amount of growth as compared to those with least utilization. Isolates of Quercus palustris grew well on 17 of 32 nitrogen sources with isolates of Q. macrocarpa exhibiting good growth on only 4 of 32 nitrogen sources.

As in poor utilization, the isolates which showed good utilization exhibited their own individual patterns with two exceptions. Identical patterns were followed between isolates of Q. marilandica and Q. maxima in one instance and between isolates of Q. bushii and Q. coccinea in another instance.

Variations in Amount of Growth in Liquid and Agar Culture

Some differences in growth of Taphrina caerulescens occurred when the same isolate was grown in liquid and agar culture with the same nitrogen source.

Workers in studying the physiology of the fungi have often observed that certain species grew better on agar medium than liquid medium. Other species, however, apparently receive no benefit. This benefit from agar has been referred to as the "agar effect".

Leonian and Lilly (1940) found that a benefit of agar was from an inorganic source. To arrive at this conclusion,

they introduced into a liquid medium the ash of agar and using Phycomyces blakesleeanus as a test organism found that it produced twice as much mycelium in the presence of ash than in the control. The experiment was continued by testing a number of trace elements known to effect the growth of fungi. Under their experimental conditions only zinc showed significant increase in growth. A chemical analysis of agar revealed a number of minor elements present such as iron, zinc, manganese, etc.

Day (1942) found that agar also contained growth factors such as thiamine.

Robbins (1939) demonstrated that he could remove other physiologically active compounds from agar by leaching it with 5 per cent aqueous pyridine.

In three experiments, Mix (1952) tested a number of species of Taphrina on potato dextrose broth. It was noted that ten isolates representing nine species of Taphrina grew poorly on potato dextrose broth. These were grown in basal medium with l glutamic acid as a nitrogen source, dextrose as a carbon source, both with and without 0.1 per cent agar. Four of the nine species showed increased growth in the presence of agar. Taphrina caerulescens, which grows well in potato dextrose broth, was not included in this experiment.

Mix (1952) grew in liquid culture with various nitrogen sources 57 host forms, representing 27 species of Taphrina. The results of his experiments were rated 0, T, +, ++ and +++,

depending upon the degree of turbidity that appeared in the 4.5 cubic centimeters of liquid medium in a small 5 inch test tube. The O indicated no growth, T a trace of growth, + poor growth, ++ average growth, and +++ good growth comparable to that obtained in potato dextrose broth. The ratings of O and T were considered as refusal of the nitrogen source.

Because certain isolates of Taphrina caerulescens refused to utilize several nitrogen sources in liquid culture (Mix, 1952), the following experiments were conducted in agar culture for comparison.

In the agar culture experiment results were recorded of one species of Taphrina--T. caerulescens. Isolate A of each host form, which was grown in liquid culture by Mix (1952) was also grown in agar culture by the writer. Isolate B of each host form was grown only in agar culture. In the cases where the isolates refused to utilize the nitrogen source in liquid culture, the results of growth obtained in agar culture were recorded for comparison (Table XXXVI). (The basis on which the growth in agar culture was rated appears earlier in the discussion of Materials and Methods.) In both experiments the liquid and agar cultures were grown without and with thiamine hydrochloride.

If the turbidity method in liquid culture and the size of the colony in agar culture were equal ratings then in nearly every case more growth was exhibited in agar culture. However, in comparing these two methods it appears that a rating of + in agar culture is probably the equivalent of a rating of T in liquid culture because of the "agar effect". If this

TABLE XXXVI

ABSENCE OF GROWTH IN LIQUID CULTURE COMPARED TO AMOUNT OF GROWTH ON AGAR CULTURE ON NITROGEN SOURCES OF T. CAERULESCENS

| Nitrogen Sources | Isolate A Liquid Culture* | | Agar Culture | | | |
|---|---|---|---|---|---|---|
| | | | Isolate A | | Isolate B | |
| | Without | With | Without | With | Without | With |
| Isolates from Quercus alba: | | | | | | |
| Calcium nitrate | 0 | 0 | + | ++ | + | ++ |
| Magnesium nitrate | 0 | 0 | + | ++ | + | ++ |
| β Alanine | 0 | 0 | 0 | 0 | T | T |
| dl β Phenylalanine | T | T | + | ++ | + | + |
| l Cysteine HCl | T | 0 | + | ++ | + | + |
| Glycine | + | T | + | ++ | + | + |
| dl Leucine | T | T | + | + | + | + |
| dl Isoleucine | 0 | 0 | + | + | + | + |
| dl Serine | T | T | + | + | + | + |
| dl Threonine | 0 | 0 | + | + | + | + |
| Isolates from Q. bushii: | | | | | | |
| β Alanine | 0 | 0 | T | T | T | T |
| l Cysteine HCl | 0 | 0 | + | + | + | + |
| dl Leucine | T | T | + | + | + | ++ |
| dl Isoleucine | 0 | 0 | + | + | + | + |
| dl Threonine | 0 | 0 | + | + | + | + |
| Isolates from Q. coccinea: | | | | | | |
| β Alanine | 0 | 0 | + | + | T | T |
| dl Alanine | T | T | + | + | + | + |
| l Cysteine HCl | 0 | + | 0 | 0 | ++ | ++ |
| Glycine | T | T | + | + | ++ | ++ |
| dl Isoleucine | 0 | T | + | ++ | ++ | ++ |
| dl Leucine | 0 | 0 | + | + | + | + |
| dl Threonine | 0 | 0 | + | + | + | + |

*Refusal to utilize nitrogen as observed by Mix (1952).

TABLE XXXVI, Con't.

| Nitrogen Sources | Liquid Culture Isolate A Without | Liquid Culture Isolate A With | Agar Culture Isolate A Without | Agar Culture Isolate A With | Agar Culture Isolate B Without | Agar Culture Isolate B With |
|---|---|---|---|---|---|---|
| Isolates from Quercus ilicifolia: | | | | | | |
| Ammonium sulfate | 0 | 0 | ++ | +++ | ++ | +++ |
| Magnesium nitrate | 0 | 0 | ++ | ++ | ++ | ++ |
| β Alanine | 0 | 0 | T | T | + | + |
| l Cysteine HCl | T | T | ++ | ++ | + | + |
| dl Isoleucine | T | T | ++ | ++ | ++ | ++ |
| Isolates from Q. laurifolia: | | | | | | |
| Ammonium sulfate | 0 | 0 | ++ | +++ | ++ | +++ |
| Calcium nitrate | T | T | ++ | ++ | ++ | +++ |
| β Alanine | 0 | 0 | + | + | + | + |
| dl β Phenylalanine | T | T | ++ | ++ | -- | ++ |
| l Cysteine HCl | 0 | 0 | + | + | T | T |
| Glycine | T | T | + | + | + | + |
| dl Histidine HCl | 0 | 0 | + | ++ | ++ | ++ |
| dl Isoleucine | 0 | T | ++ | ++ | + | ++ |
| dl Leucine | 0 | T | ++ | ++ | + | + |
| l Hydroxyproline | 0 | 0 | + | + | + | + |
| dl Threonine | 0 | 0 | + | + | + | + |
| Isolates from Q. macrocarpa: | | | | | | |
| Ammonium chloride | 0 | 0 | ++ | ++ | ++ | +++ |
| Ammonium phosphate | 0 | 0 | + | ++ | ++ | +++ |
| Ammonium sulphate | 0 | 0 | ++ | ++ | + | ++ |
| Ammonium tartrate | 0 | 0 | + | ++ | ++ | +++ |
| Calcium nitrate | 0 | 0 | + | + | + | + |
| Magnesium nitrate | 0 | 0 | + | ++ | + | ++ |
| Potassium nitrate | T | T | + | + | ++ | ++ |
| Sodium nitrate | 0 | 0 | + | + | + | + |
| β Alanine | 0 | 0 | 0 | T | T | T |
| dl Alanine | T | T | T | T | + | + |
| dl β Phenylalanine | T | T | ++ | ++ | ++ | ++ |
| Glycine | 0 | 0 | + | + | + | + |
| l Cysteine HCl | 0 | + | T | T | T | T |
| dl Isoleucine | 0 | 0 | + | + | + | + |
| dl Leucine | 0 | 0 | + | + | + | + |

TABLE XXXVI, Con't.

| Nitrogen Sources | Liquid Culture Isolate A | | Agar Culture Isolate A | | Agar Culture Isolate B | |
|---|---|---|---|---|---|---|
| | Without | With | Without | With | Without | With |
| Isolates from Q. macrocarpa, Con't.: | | | | | | |
| dl Methionine | 0 | 0 | T | + | T | + |
| l Proline | 0 | 0 | + | + | + | + |
| l Hydroxyproline | 0 | 0 | + | + | + | + |
| dl Serine | 0 | 0 | + | + | + | + |
| dl Threonine | 0 | 0 | T | T | + | + |
| Isolates from Q. marilandica: | | | | | | |
| β Alanine | 0 | 0 | + | + | T | T |
| l Cysteine HCl | 0 | 0 | T | T | ++ | + |
| dl Isoleucine | 0 | 0 | + | + | ++ | ++ |
| dl Leucine | 0 | 0 | ++ | ++ | ++ | ++ |
| Isolates from Q. maxima: | | | | | | |
| Magnesium nitrate | T | 0 | ++ | +++ | ++ | +++ |
| β Alanine | 0 | 0 | T | T | T | T |
| l Cysteine HCl | T | 0 | ++ | + | ++ | + |
| dl Isoleucine | 0 | 0 | + | + | + | + |
| dl Leucine | 0 | T | + | + | + | + |
| dl Threonine | 0 | 0 | + | + | + | + |
| Isolates from Q. nigra: | | | | | | |
| Magnesium nitrate | 0 | 0 | + | ++ | ++ | ++ |
| Calcium nitrate | 0 | 0 | ++ | +++ | ++ | +++ |
| β Alanine | 0 | 0 | + | + | + | + |
| l Cysteine HCl | 0 | 0 | T | T | + | + |
| dl Isoleucine | 0 | 0 | + | + | + | + |
| dl Leucine | 0 | + | ++ | ++ | + | + |
| l Hydroxyproline | 0 | 0 | + | + | + | + |
| dl Threonine | 0 | 0 | + | + | + | + |
| Isolates from Q. palustris: | | | | | | |
| Calcium nitrate | 0 | 0 | ++ | ++++ | ++ | +++ |
| Magnesium nitrate | T | T | ++ | +++ | ++ | +++ |
| β Alanine | 0 | 0 | T | T | T | T |
| dl Alanine | T | T | + | + | + | + |
| l Cysteine HCl | T | 0 | + | + | ++ | + |

TABLE XXXVI, Con't.

| Nitrogen Sources | Liquid Culture Isolate A | | Agar Culture Isolate A | | Agar Culture Isolate B | |
|---|---|---|---|---|---|---|
| | Without | With | Without | With | Without | With |
| Isolates from Quercus palustris, Con't.: | | | | | | |
| Glycine | T | T | + | + | + | + |
| dl Isoleucine | 0 | 0 | + | + | + | + |
| dl Leucine | T | 0 | ++ | ++ | ++ | ++ |
| dl Threonine | 0 | 0 | + | + | + | + |
| Isolates from Q. prinoides: | | | | | | |
| Ammonium phosphate | 0 | 0 | + | ++ | + | ++ |
| Ammonium sulphate | 0 | 0 | + | ++ | + | ++ |
| Ammonium tartrate | 0 | 0 | ++ | +++ | ++ | +++ |
| Calcium nitrate | 0 | 0 | + | + | + | ++ |
| Magnesium nitrate | 0 | 0 | ++ | ++ | + | + |
| Potassium nitrate | T | T | + | + | + | + |
| Sodium nitrate | 0 | 0 | + | + | ++ | ++ |
| β Alanine | 0 | 0 | T | T | T | T |
| dl Alanine | T | T | + | + | ++ | ++ |
| l Cysteine HCl | 0 | + | 0 | 0 | 0 | 0 |
| Glycine | 0 | 0 | + | + | + | + |
| dl Isoleucine | 0 | 0 | + | + | + | + |
| dl Leucine | 0 | 0 | + | + | + | + |
| dl Methionine | 0 | 0 | + | + | + | + |
| l Proline | 0 | 0 | + | + | + | + |
| l Hydroxyproline | T | T | + | + | + | + |
| dl Threonine | 0 | 0 | + | + | + | + |
| Isolates from Q. velutina: | | | | | | |
| Magnesium nitrate | 0 | T | ++ | +++ | ++ | +++ |
| β Alanine | 0 | 0 | T | T | T | T |
| l Cysteine HCl | T | T | T | T | T | T |
| dl Isoleucine | 0 | 0 | ++ | ++ | ++ | ++ |
| dl Leucine | 0 | 0 | + | + | + | + |
| dl Threonine | 0 | 0 | + | + | + | + |

TABLE XXXVI, Con't.

| Nitrogen Sources | Liquid Culture Isolate A Without | Liquid Culture Isolate A With | Agar Culture Isolate A Without | Agar Culture Isolate A With | Agar Culture Isolate B Without | Agar Culture Isolate B With |
|---|---|---|---|---|---|---|
| Isolates from Quercus virginiana: | | | | | | |
| Calcium nitrate | 0 | 0 | ++ | +++ | ++ | +++ |
| Magnesium nitrate | 0 | 0 | ++ | ++ | ++ | +++ |
| β Alanine | 0 | 0 | T | T | T | T |
| dl β Phenylalanine | 0 | T | + | ++ | + | ++ |
| l Cysteine HCl | 0 | 0 | 0 | 0 | 0 | 0 |
| Glycine | T | T | + | ++ | + | ++ |
| dl Isoleucine | T | T | ++ | ++ | ++ | ++ |
| dl Leucine | 0 | T | ++ | ++ | ++ | ++ |
| l Hydroxyproline | T | 0 | + | + | + | + |
| dl Threonine | T | 0 | + | + | + | + |

supposition is correct, the differences between the degree of refusal in liquid culture and agar culture is not as great, although more growth did occur in agar culture.

To check the effect that agar had on isolates of Taphrina caerulescens, an experiment was set up using a basal medium with no nitrogen source present. Dextrose was the carbon source and 2 per cent agar was added. After the growth period of 21 days every isolate of T. caerulescens exhibited growth sufficient to receive a + rating. The initial pH had been 4.8 and the final pH in most cases was near 5.2.

Allowing some increase in growth due to the presence of agar, there is correlation between the growth of most of the isolates when results of liquid culture and agar culture are compared. However, there are some exceptions. The most striking exceptions are the refusal of isolates from Quercus ilicifolia, Q. laurifolia, Q. macrocarpa, and Q. prinoides to utilize several sources of ammonium and nitrate nitrogen in liquid culture but to exhibit ++, +++ and ++++ growth on the same sources in agar culture. This difference in behavior can not be explained at the present time.

Another exception is exhibited by isolates from Q. alba, Q. maxima, Q. nigra, Q. palustris, Q. velutina and Q. virginiana refusing to grow on several sources of nitrate nitrogen in liquid culture but exhibiting good growth on the same sources in agar culture.

The other variations probably come within the margin of experimental error. The constant increased growth in

agar culture as compared to liquid culture shows the beneficial presence of agar.

## SUMMARY AND CONCLUSIONS

1. Desmazières (1848) first described the pathogen of oak leaf blister as Ascomyces caerulescens Mont. and Desm. Later revisions followed, but Mix (1949) recognized only one species, Taphrina caerulescens (Mont. & Desm.) Tul.
2. Results of attempts at artificial inoculation of species of Quercus with T. caerulescens have so far been inconclusive. A life history of T. caerulescens is ~~proposed~~ suggested.
3. In a preliminary account of the distribution of oak leaf blister, 33 species of Quercus located in 33 states and 4 provinces have been found as hosts of T. caerulescens in United States and Canada.
4. Variations in size and shape of asci do occur but ~~is~~ are not correlated with any particular ascus size or group of hosts. The bases of some asci bear rhizoidal elongations indicating a tendency toward formation of intercellular mycelium. Otherwise mycelium is conjectured to be subcuticular.
5. Twenty-six isolates of T. caerulescens from 13 hosts were grown in agar culture on 32 different nitrogen sources, both without and with thiamine hydrochloride.
6. Data was taken on amount of growth, changes in hydrogen-

ion concentration, and in pigment formation.

7. In an analysis of variance three sources of variance were considered. The presence or absence of thiamine hydrochloride had a significant (P less than .01) effect on growth of Taphrina caerulescens contributing 54.1 per cent of the total variance of the experiment. Differences in media due to the presence of different nitrogen sources had a significant (P less than .01) effect on the growth of T. caerulescens contributing 2.4 per cent of the total variance. No significant differences in growth were found due to the Quercus species from which the isolates were obtained.

8. Taphrina caerulescens utilizes ammonium nitrogen more readily than nitrate nitrogen as indicated by a comparison of hydrogen-ion concentrations. However, no difference is evident in a comparison of its mean growth.

9. Sixteen amino acids and asparagine were used as sources of nitrogen but resultant growth was slight and hydrogen-ion concentration changes small.

10. Peptone and urea were used as sources of nitrogen. Peptone ranked among the highest as a source of nitrogen with only slight change in pH. Urea induced less growth but more change in pH.

11. The color of the colonies of T. caerulescens does change when grown on different sources of nitrogen both without and with thiamine hydrochloride. Variation in this

respect occurs between the host forms with only small variation between isolates ~~of~~ from the same host.

12. A comparison of host forms was made regarding the poor and good utilization of nitrogen. No two host forms followed the same pattern of growth on poor utilization of nitrogen; less variation was exhibited between host forms in good utilization of nitrogen with two instances of identical growth patterns.

13. Only small variations in amount of growth occurred between liquid and agar cultures with the exception of several isolates on ammonium and nitrate sources exhibiting distinct differences.

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